An End to Pounding

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A new mechanical floor milling system in use in Africa

Paul Eastman

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE
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CANADA

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An End to Pounding:

A New Mechanical Flour Milling System in Use in Africa

Paul Eastman*

**The author, a former employee of the Agriculture, Food and Nutrition Sciences Division of IDRC, was hired as a consultant to prepare this booklet on behalf of the Postproduction Systems Group of AFNS.*

CONTENTS

FOREWORD Since 1972, the International Development Research Centre (IDRC) has supported several research projects whose purpose was the development of systems by which to produce acceptable flour and other milled products from the major cereal and grain legume crops of the semi-arid tropics. Projects have been supported in Botswana, Ghana, Nigeria, Senegal, Sudan, and one is about to begin in Tanzania. The Prairie Regional Laboratory (PRL) of the National Research Council of Canada in Saskatoon has been much involved in the related engineering research and development.

Various prototype dehullers and grinders have been tested under laboratory, pilot, and small-scale commercial conditions. Before establishing the commercial mills, scientists in the developing country where the mill was to be installed, assisted by IDRC, conducted consumer preference and marketing studies, and others were given training in cereal mill management.

From the collective experience gained, we believe it is now possible to recommend a dry milling process applicable to the decortication and conversion to flour and other milled products of a variety of cereal grains and legumes, particularly those grown in the semi-arid tropics. Variations on the basic principle of abrasive decortication have been shown to be technically and economically viable under several different operating conditions.

The essential component, central to the system, is the dehuller, described in this monograph; it was originally designed at the PRL in Saskatoon and later modified at the Rural Industries Innovation Centre (RIIC) in Kanye, Botswana. Consequently, it has been named the PRL/RIIC dehuller. The essential principle can be applied to both batch and semicontinuous-flow systems.

Though the milling systems described were designed primarily for the processing of sorghum and pearl millet, they have proved satisfactory for several other cereals and food legumes. One of the main attractions of the systems appears to be their flexible capacity to process grains of widely different sizes, without significant mechanical adjustment.

This booklet is not intended to be a comprehensive instruction manual; rather it attempts to review the accumulated knowledge and experience gained during the development, testing, and operation of the several mills referred to. It is hoped that this book will be of interest to a wide audience including those who elaborate agricultural and industrial policy, owners of small-scale industries, and cereal technologists.

The following people collaborated with the author during the preparation of this booklet: Nancy Eisner and Chuck McFarlane, who worked on the project in Botswana and made available to him some background material during the compilation of the book; Robert Reichert of the NRC Prairie Regional Laboratory; and Alf Petersen of the University of Alberta; also the Postproduction Systems Group of AFNS. That group, under Associate Director Robert For-

rest, includes: William Edwardson, Sally Vogel, and Gordon Yaciuk. More details can be obtained from the PPS group at Suite 304, 10454 Whyte Avenue, Edmonton, Alberta, Canada T6E 4Z7.

The comments of all who receive this publication would be most welcome.

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THE NEED Substantial quantities of cereals and grain legumes are produced in the semi-arid regions of the world. In 1977, The Food and Agriculture Organization (FAO) estimated that more than 9.2 million tonnes of millet and 9.4 million tonnes of sorghum were produced in Africa alone — virtually all of which was used directly for human consumption. Overall, millet and sorghum are the most important staple foods throughout the Sahelian zone.

The importance of cereals (and grain legumes) will surely increase in the future, especially in the diets of the poorest people. As a result, it is safe to say that anything that encourages production and improves availability of essential cereals and grain legumes in a form demanded by consumers takes on particular significance in most semi-arid regions of the world.

Within the Third World, despite the high level of consumption of sorghum and millet, despite the reliance on sorghum and millet as staple foods, and despite consumers' preferences for flour made from sorghum and millet, the industrial production and commercialization of flour from these cereals has never been adequately established. The production of flour is still the responsibility of each individual household. Traditional manual milling is still universally practiced; the grain is usually soaked in water to soften the seed coat, pounded to remove this thin layer, winnowed, moistened a second time, and pounded into flour by hand using a mortar and pestle or ground in a small mechanical hammer or plate mill.

From a social and economic standpoint, some people argue that traditional processing is the most appropriate technique for many parts of the world. However, there are equally good and more persuasive arguments that show a genuine need for a simple dry mechanical process to mill sorghum, millet, cowpeas, and other cereals and grain legumes into acceptable and good quality flours:

- Quite simply, sorghum and millet are usually the preferred staple household foods in areas where these cereals are grown. In addition evidence shows that the demand for sorghum and millet flour is strong and will increase if a supply of flour with acceptable texture, taste, and colour can be guaranteed. A dry mechanical system is one way in which a good quality flour can be supplied in sufficient quantities to meet commercial requirements.

• With increases in urbanization and in disposable incomes within parts of the Third World, the demand for preprocessed and convenience foods is accelerating. For example, commercially milled wheat and maize flour when available at an affordable price (usually imported) is purchased in favour of the preferred, but unprocessed and therefore less convenient, sorghum and millet. As a result, markets for locally grown sorghum and millet usually diminish, incentives for local production deteriorate, and foreign exchange reserves dwindle, as they are used to meet the demand for imported, preprocessed flours.[1]

• Unlike maize and wheat, sorghum and millet are relatively drought-tolerant and can be grown in marginal areas where low rainfall precludes the production of other cereals. When imported flour causes the demand for locally grown sorghum and millet to diminish, there are few crops that can be substituted without large investments in irrigation. Consequently, in many semi-arid regions of the world, production and marketing of sorghum and millet are essential for a viable agricultural community. The additional market for locally grown grain that would result from the presence of a processing facility would encourage increased production.

• Traditional methods for making flour are extremely labour-intensive. Several informal surveys done on the role of women in agriculture have shown that a woman can devote 2–5 hours a day to processing sorghum and millet grain for her family -- time and energy that could be more profitably spent on other activities.

• Some researchers believe that the labour force will soon be insufficient to do both the traditional processing of cereals and the cultivating of additional quantities of grain. For example, in regions where young women do most of the processing, they are being encouraged to gain an education. Consequently, some processing and some production tasks will be curtailed.

• In the traditional, wet-milling process, the flour tends to become rancid and mouldy within a day or so after grinding. In contrast, flours that are produced by a dry method have a much longer shelf-life.

• The most convincing reason for developing a simple, dry mechanical milling process is that people in the Third World want it. In a survey done in several villages in Senegal, the three most desirable additions to village life were reported as a reliable water supply followed by grinding and dehulling facilities that would produce an acceptable product from local grains.

• Many individuals believe that any improvements in the level of living for millions of people in the Third World must result from improvements based on locally available materials and resources. Traditional processing tends to encourage the status quo, whereas mechanical processing has the potential to stimulate the economy and encourage the use of local resources.

With the above in mind, the IDRC supported and helped design several research projects to develop an improved milling system that was capable of processing locally grown cereals into acceptable flours.

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[1]FAO reports that between 1961 and 1977, imports of wheat, rice, and maize to Africa increased between 5% and 10% a year, whereas the production of sorghum and millet increased 0.2–1% annually.

2

DEVELOPMENT One of the first problems in designing a mechanical flour milling system was to devise a method to remove the thin seed coat from sorghum, cowpeas, and other cereals and grain legumes. Consequently, a research project was initiated at the Prairie Regional Laboratory in Canada to develop an efficient and effective dehuller.

At the same time in Nigeria, another research project was launched that aimed at perfecting a milling system incorporating the dehuller. A systems approach was followed throughout the project in that, from the beginning, the mill was considered to be simply a part of an overall postproduction system. Properly considered, this system encompasses the delivery of a crop from the time and place of harvest to the time and place of consumption with minimum loss, maximum efficiency, and maximum return to all involved (Fig. 1). The Nigerian project not only investigated and tested new milling technologies but also studied consumer preferences, grain and flour marketing, the evaluation of milled products, new food development, mill management procedures, and so forth.

The importance of these supporting studies cannot be overemphasized. For example, in an early study of grain marketing in Nigeria, it was observed that only 10- 15% of all farm output actually entered formal marketing channels. As a result, before any milling technology could be considered practicable and realistic, a dependable grain supply system was devised.

The mill project in Nigeria proved that it was possible to produce flour commercially and profitably from locally available, ungraded varieties of sorghum, maize, and cowpeas using a continuous-flow, dry mechanical milling system. Unfortunately, when local dark, blue-green millet was dehulled and ground, some discoloration occurred, but studies are continuing so that this difficulty can be overcome.

Because of the experience gained in Nigeria, it seemed wise to test the continuous-flow milling system under different conditions and on different types and varieties of crops. Similar mills were, or are being, established in

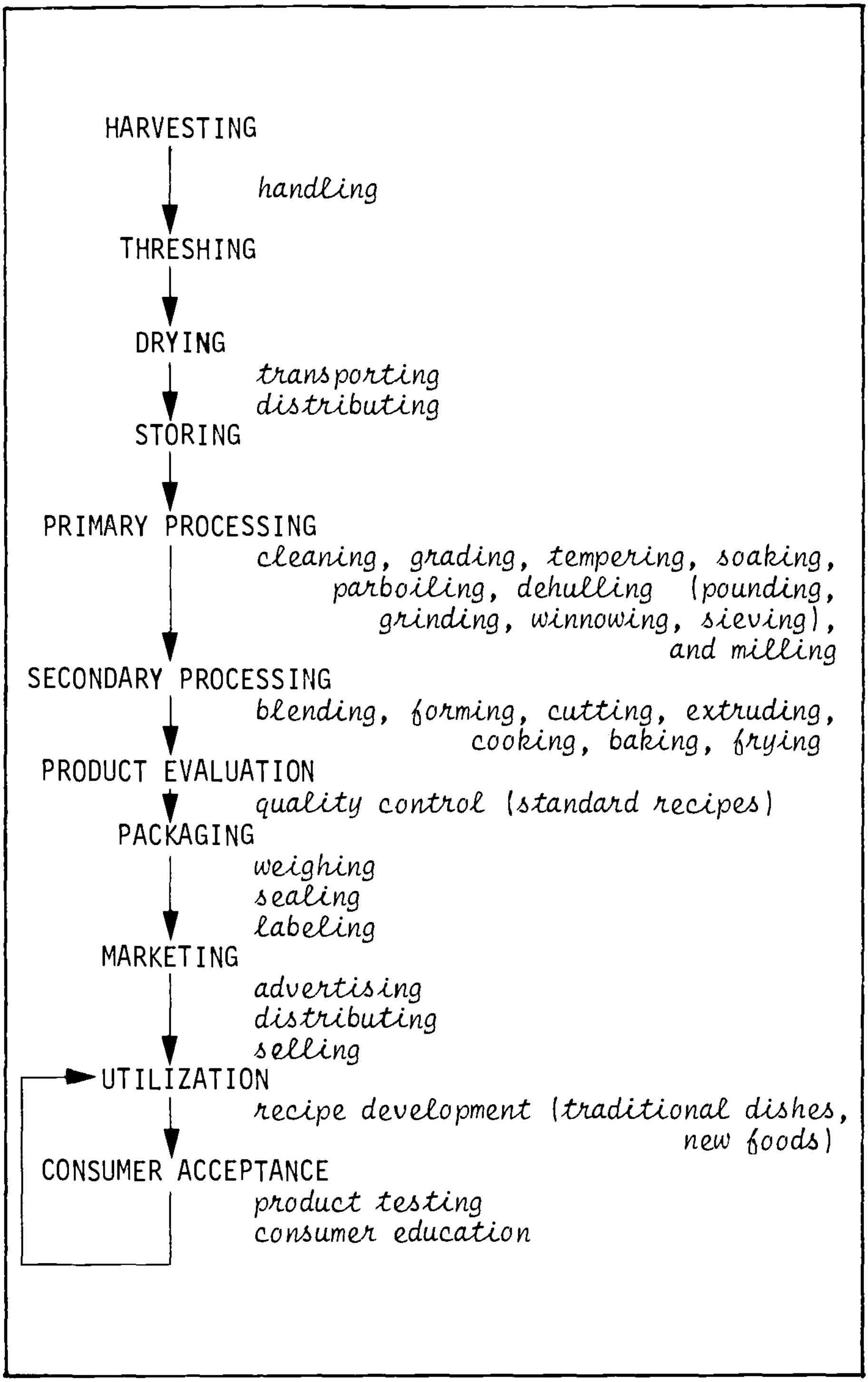

Fig. 1. Schematic diagram of a total postproduction grain system.

Senegal, Ghana, Sudan, and Botswana. In Senegal, millet is being processed; in Ghana, legume flour (particularly cowpea flour) is being produced; and in Sudan, a comparison and evaluation of sorghum processing using five milling systems (including the one described in this booklet) is being undertaken.

In Botswana, not only is a continuous-flow mill operating, but also a new version has been designed and is functioning on a commercial basis. People in several rural African communities expressed a need for a batch mill that would process their small individual quantities of grain into flour for a predetermined service fee. Consequently, in 1978, the IDRC established a project at the Rural Industries Innovation Centre (RIIC) that aimed, and succeeded, at developing and building a smaller-scale batch dehuller and incorporating it in a service mill. This adaptation of the original continuous-flow design has also proved to be an extremely effective and useful dry milling process.

THE FIRST PILOT MILL

The first continuous-flow pilot mill to operate successfully was located in Maiduguri, a sorghum- and millet-growing area of Nigeria. Before a good quality flour was produced from the mill, a number of modifications were made to the original design. However, the mill consisted of six basic parts:

- A *precleaner,* which removes stones and other foreign matter from the grain. As all the grain that was purchased in the Nigerian village markets for processing in the mill was relatively free of stones and other debris, the precleaner was eliminated from the system. Even though it has proved to be unnecessary in other test locations as well, it can be included if locally available grains are contaminated with foreign matter.
- A *dehuller,* which removes the seed coat from the grain. The original dehuller, which was developed at the Prairie Regional Laboratory in Canada, was basically a modified barley thresher. During testing in Nigeria, several design changes were made to the dehuller to increase its efficiency and throughput.
- A *grinder,* which grinds the dehulled cereal into flour. Several hammer and plate grinders were tested using the dehulled grain from the dehuller. Most hammer and plate mills produced an acceptable flour, but a Jacobson #160[2] Pulverator (hammer mill) was superior because it did not become clogged as did many other grinders.
- A *flour sifter,* which separates the flour into different-sized particles. In Nigeria and in subsequent test sites, it was found that a change in the screens on the hammer mill produced an acceptable flour without the sifter. Although the sifter does not seem necessary, it can be included in the system if needed. Of the various sifters that were tested, the Kason Centri-Sifter was preferred because it is a relatively simple, one-screen design. Furthermore, it is compact and produces only two fractions of flour — a sufficient variety for Nigerian and other conditions. Large, vertical sifters that are commonly used to sift wheat flour are unnecessarily complex.

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[2]The Jacobson Pulverator provides a 360° screen that completely encircles the rotor, permitting rapid escape of properly sized particles from the grinding chamber. Materials that do not pass through the screen immediately are thrown into the "teardrop" area and back into the hammers. The Jacobson #195 Pulverator has proved more effective than the #160 for commercial, or continuous-flow, processing.

- A *power source* (diesel engines), which drives the dehuller, grinder, and, if needed, the sifter and precleaner.
- A *weighing and sealing unit,* which weighs and packages the flour in small polyethylene bags. Although a manual weighing unit was used in Nigeria, subsequent testing has shown that an automatic weigher and a pedal-operated sealing unit are the best combination to use with the polyethylene bags. If cotton bags are used to package the flour, a sewing machine, rather than a heat-sealing unit, is required.

The equipment used in Nigeria was selected and designed so that various parts were matched and would work together. However, throughout testing in Nigeria and later in Botswana and elsewhere, the mill proved to be flexible. For example, although a hammer mill is preferred, it is possible to use a plate mill or a combination of plate and hammer mills; it is possible to operate the mill to produce both flour and dehulled cereal; it is possible to add or remove the sifter and precleaner as needed; an identical line of equipment can be easily added or two daily work shifts can be started to double output; and so forth.

Essentially, throughout the entire design and testing phases, the only new technological development in the mill was the dehuller.

3

THE DEHULLER Because many grains have a fibrous, coloured hull, which may also contain bitter tannins, the hulls are removed from the grains before consumption. A number of mechanical dehulling methods have been developed. For wheat, a white flour is obtained by "reduction milling" during which the grain is progressively ground and sifted in a series of roller mills. This method has not been widely used to mill other grains because the structure of other cereals is not compatible with the equipment or because the scale, complexity, and cost of the roller mill cannot be justified.

For other cereals and grain legumes, simpler dehulling, peeling, or polishing equipment has been developed. Many of the machines use some form of Carborundum stone to abrade or wear off the seed coat. In most cases the stone is rotated inside a metal housing. As the kernels move through the unit between the stones and the housing, the seed coat is abraded. The Carborundum stones may be in the shape of a cylinder, a truncated cone, or a series of disks mounted on a central shaft. The metal housing, which conforms to the shape of the Carborundum stones, may be perforated to allow the fine abraded material (seed coat) to be removed either with or without the aid of a fan. Essentially, the first dehuller developed at PRL is an adapted version of this basic abrasive design.

In the PRL dehuller (Fig. 2), a series of Carborundum stones are mounted on a horizontal shaft at about 1.5–3.0 cm intervals. The rotor so formed is mounted in a metal case with a clearance of 1.5–3.0 cm at the sides and around the bottom of the rotor. A screened, air inlet is provided along one side of the top and an air outlet at the opposite side. By connecting the air outlet to an aspiration system, the designers ensured that the fine particles formed during abrasion are automatically removed. The unit may be operated without either air inlets or outlets in which case the finely ground material leaves the metal case with the dehulled kernels and must be separated by other means such as external aspiration or hand sieving.

Grains are fed into one end of the dehulling unit at a uniform rate and exit at

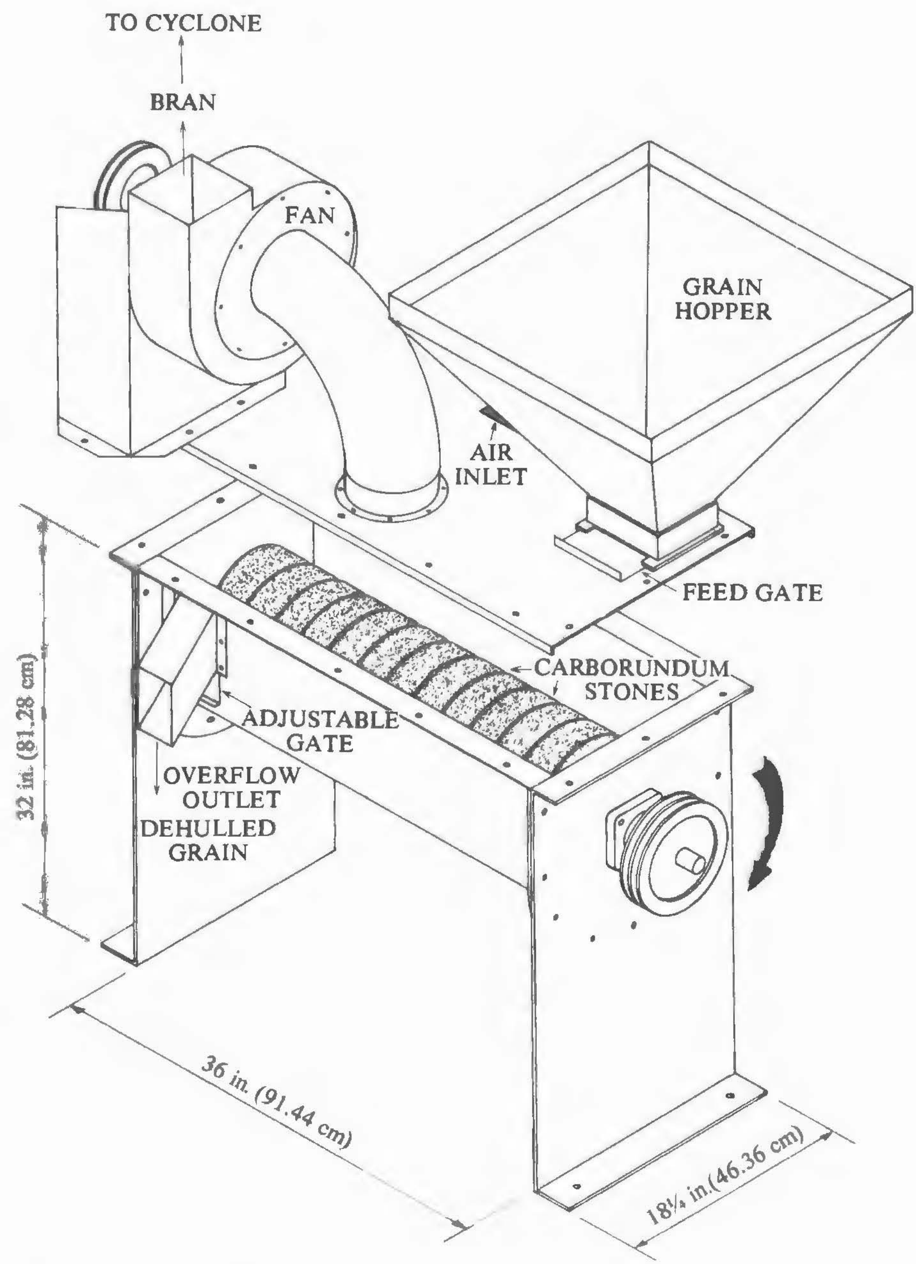

Fig. 2 The PRL dehuller is identical to the PRL/RIIC dehuller except that the latter has a hinged door on the bottom to let any residual dehulled cereal drop into a collecting basin.

the opposite end through an adjustable overflow outlet. The level of grain in the unit is regulated such that 50–100% of the rotor is covered during operation.

The PRL dehuller has performed quite satisfactorily when operating in a continuous-flow milling system. However, in many rural communities in the

Third World, it is common practice for homemakers to process flour in small batches and only as required for consumption. The PRL dehuller is not designed to dehull small quantities of grain. Instead it operates most profitably and efficiently with a continuous flow of grain that comes from a stockpile, through the dehuller (and other processing equipment described later), and is ultimately sold as packaged flour.

At the Rural Industries Innovation Centre (RIIC) in Botswana, the original PRL dehuller was modified so that small batches of grain can be processed. This adapted version of the dehuller is also capable of functioning in a manner similar to the PRL model and is now the recommended design for use in either a service or a continuous-flow milling system. A mill that incorporates this PRL/RIIC dehuller has all the flexibility of mills using the earlier design and has the added advantage of being able to function in a batch system, in a continuous-flow setup, or in a combination of the two.

The PRL/RIIC dehuller and the PRL dehuller are almost identical; they differ in the following ways:

- Although it has the same throughput, the PRL/RIIC dehuller is smaller. The PRL dehuller requires a minimum 20 kg of grain, whereas the PRL/RIIC dehuller requires only 10 kg of grain to become operational.
- The PRL dehuller uses 27-cm diameter stones, and the PRL/RIIC dehuller uses 22-cm diameter stones. Even though the length of the two housings is the same, the PRL/RIIC dehuller is slightly narrower than the PRL dehuller.
- The PRL/RIIC dehuller operates at higher revolutions per minute than does a stone-equipped PRL dehuller. As a result, when the two dehullers operate continuously, there is little difference in throughput.
- The most unique feature of the PRL/RIIC dehuller is its emptying device. In the PRL dehuller, there is always a residual amount of dehulled cereal in the bottom of the rotor, which makes service dehulling impractical. On the PRL/RIIC dehuller, a reinforced hinged door has been added to the bottom of the casing. Also, a funnel has been attached so that even when the dehuller is operating, a lever can be raised, the door will open, and any residual, dehulled grain will drop through the funnel into a collecting basin. In this way, individual quantities of grain as small as 10 kg can be dehulled without stopping the dehuller.

A more recent development suggests that it is possible to replace the Carborundum stones with lighter resinoid disks. By their nature, the Carborundum stones must be formed in relatively thick sections so that they may be safely rotated at speeds of 1000 rpm or more. As a result, the stones are quite heavy. The thickness of the stones also means that only a limited amount of abrading surface area is obtained for a given weight.

The resinoid disks being tested are not new designs but have been widely used for cutting steel and concrete. The disks are made by bonding of an aluminum oxide abrasive into plastic. Such disks are formed into very thin, light, but strong sections that can be safely rotated at speeds of more than 6400 rpm.

The use of the resinoid disks in the dehuller provides more than twice the amount of abrasive surface (at only one-fourth the weight of Carborundum stones). As a result, power consumption per kilogram of grain dehulled is lower. The cost of the resinoid disks is also lower.

In preliminary tests on sorghum in the laboratory, it has been found that extraction rates and throughput are similar for dehullers using the Carborun-

The dehuller with the top removed to illustrate grain passing over the Carborundum stones.

dum stones or resinoid disks. However, because the resinoid disks are rotated at higher speeds than are the stones, more kernel cracking occurs and may result in less efficient hull removal. In summary, the evidence that resinoid disks are superior is not conclusive at this time. Further testing with local varieties of grain is needed to determine the feasibility of replacing the Carborundum stones with the resinoid disks.

4

THE MILLING SYSTEMS As mentioned previously, the PRL/RIIC dehuller is capable of operating in a continuous-flow system, in a service mill setup, or in a combination of the two. In this section the continuous-flow and service mills are described.

THE CONTINUOUS-FLOW MILLING SYSTEM

Through repeated testing with different grains in different locations and with various kinds of models of equipment, a reliable, simple, and profitable continuous-flow milling system has been developed, which produces a good quality sorghum, maize, and cowpea flour. Although several building and equipment layouts are possible, Fig. 3 shows a setup that is capable of processing approximately 1400 tonnes[3] of grain a year operating on one 8-hour shift[4] for 250 days a year. Twice the output can be achieved by operating two 8-hour shifts or by installing a second identical line of equipment and operating both lines on one 8-hour shift.

In a continuous-flow system, the recommended equipment line consists of two PRL/RIIC dehullers, one hammer mill, one auto-weigher, one heat sealer, one generator, one compressor, and two diesel engines. The equipment is arranged in a straight line to minimize material handling and to promote good hygiene by segregating the grain and flour at opposite ends of the milling unit. To discourage insect infestation in the mill and to ensure good sanitation practices, it is suggested that a maximum of 5 days' grain storage capacity be allowed in the mill building. If grain supply systems make it necessary to store more than a 5-day requirement, a separate storage facility should be constructed

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[3]The throughput of the mill will vary depending on the type and variety of grain being processed.

[4]The equipment line is expected to run 6 hours in each 8-hour shift with the remaining 2 hours devoted to equipment servicing, record keeping, and cleanup.

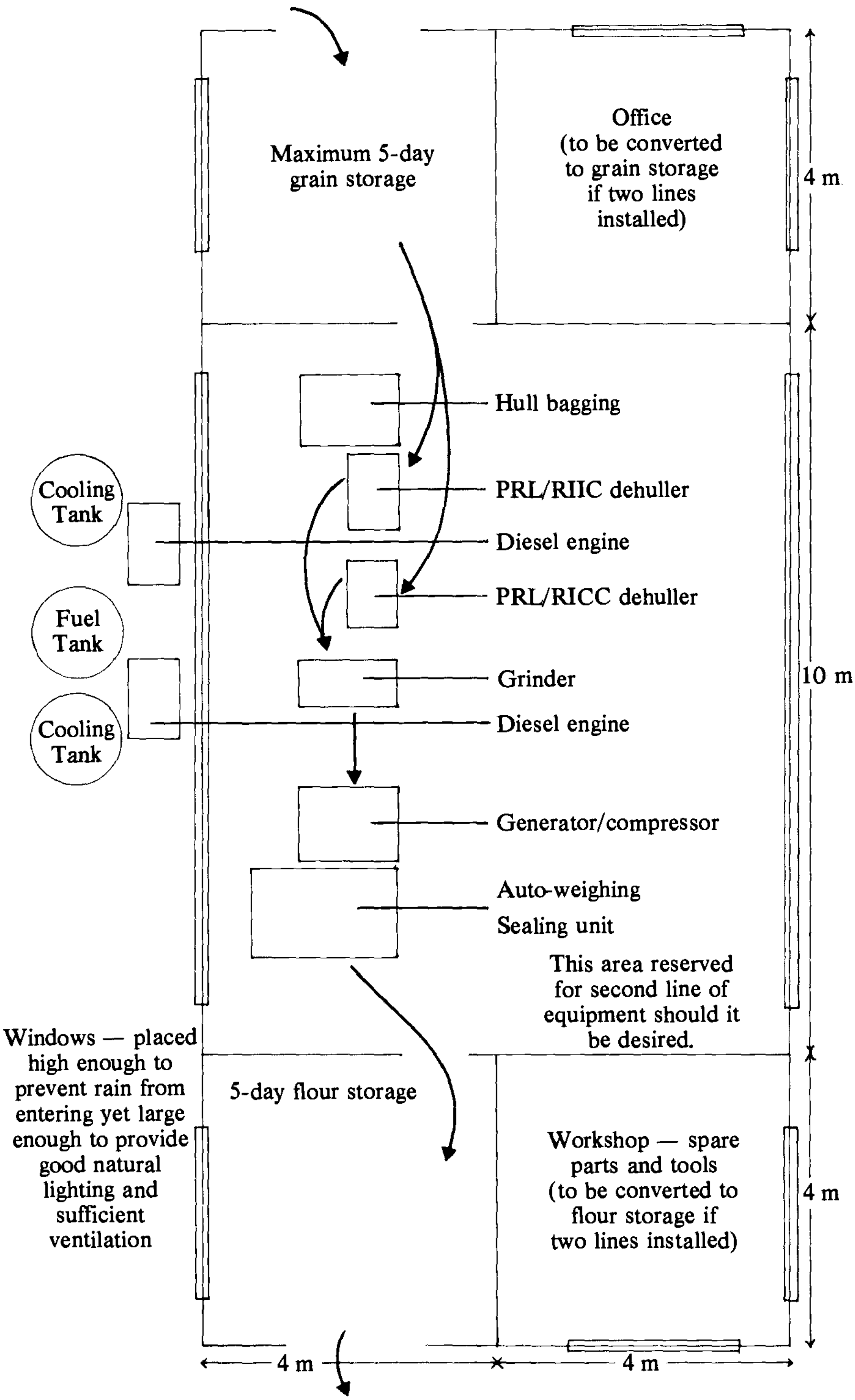

Fig. 3. Sample floor plan for a continuous-flow mill.

adjacent to the mill building. Local agricultural authorities should be contacted to discuss and recommend appropriate storage and fumigation plans.

The equipment line is placed against the outside wall of the building to facilitate the connection with fuel and cooling tanks that are located outside the structure. The engine exhaust and the dust from the aspirators are also piped through the walls. Also the engines may be mounted outside the main building if longer belts are used and extended through openings in the wall. Such a setup helps to reduce engine noise within the mill.

In the recommended layout, two PRL/RIIC dehullers are necessary to achieve a profitable volume and also to match the grinding capacity of the hammer mill. The dehullers are adjusted so that sufficient seed coat is removed to produce a flour that satisfies consumers' wishes. The adjustments that can be made include increasing or decreasing the amount of time that the kernels are retained inside the dehullers or passing the grain through a second time. In most cases, only one pass through the dehuller is necessary because a suitable flour can usually be produced simply by an alteration of the retention time.

As each dehuller requires an 8-hp power source, the two dehullers are driven by a line shaft connected to a 20–25-hp, water-cooled, diesel engine.

The hulls (seed coat) are removed from the dehullers by an aspirator and are discharged through a cyclone into sacks. This collected bran can be subsequently sold, usually for animal feed.

The dehulled grain is then transferred to the hammer mill either by hand or by an auger or elevator. The automated auger system may be desirable because it reduces waste and encourages good hygiene. Grinding is accomplished by a Jacobson #195 Pulverator. The grinder has a power requirement of 12–16-hp and is connected to a second 20–25-hp, water-cooled, diesel engine that also drives the electric generator.

After being ground, the flour is pneumatically conveyed to another cyclone that discharges into the auto-weigher. A "Y" valve is recommended between the cyclone and the hopper on the auto-weigher so that flour can be directed into bulk sacks should the need arise.

Because of the volume of output, it has proved difficult to bag and weigh the flour by hand. Consequently, automatic weighers that discharge an exact amount of flour into a hand-held bag are suggested. Some auto-weighers require a compressor to operate the dump gate.[5] However, an all-electric screw mechanism is functioning in Nigeria with acceptable accuracy and speed.

Two-kilogram polyethylene bags have proved to be appropriate packages for the flour because they permit the consumer to view the product, they are relatively inexpensive, and they can be tightly closed with a heat sealer. The use of larger polyethylene bags is not advised because they usually cannot withstand the pressure from the flour and they split open when handled. Hand- or machine-stitched cotton bags (5 kg or more) are also quite suitable. In fact, some people suggest that cotton packaging should be encouraged in favour of polyethylene bags simply because the demand for the bags might promote a secondary cottage industry. In the selection of packaging materials, another important factor to consider is cost. The cost of polyethylene bags is bound to escalate in the future because they are petroleum-derived products.

The heat sealer, air compressor, and auto-weigher require a single-phase

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[5]As an alternative to a compressor-driven weigher, a spring-loaded weigher has proved to have value. Further testing will be required before it can be recommended for the mill.

Grain storage for a continuous-flow mill.

power supply. This is reliably provided by an 8000-watt generator that is driven by the surplus power from the second diesel engine driving the hammer mill. In addition, the generator has sufficient capacity to provide artificial lighting for the mill that will enable longer hours of operation.

Two identical diesel engines are specified.[6] One drives the two dehullers, and one drives the grinder and generator. Water-cooled engines are recommended because air-cooled engines operating under continuous load tend to cause problems during the hot, dry season of many semi-arid parts of the world. Diesel engines are suggested because they are relatively rugged, comparatively inexpensive to operate, and are easy to maintain. However, petrol or electric engines can also be used with good results. Each power source has advantages and disadvantages that must be evaluated before a final choice is made. It must be stressed that before electric engines are chosen, a reliable source of electricity must be available — usually not the case in many areas of the Third World. "Brown outs" have disastrous effects on equipment maintenance and plant viability. In addition, there is little to be gained by installing a generator of

[6]Lister diesel engines have successfully powered the milling equipment but any other make can be used provided it has proved to be reliable and provided parts and servicing are readily available.

sufficient size to operate two electric engines. In summary, electric engines should be considered only when a reliable power supply is guaranteed.

The diesel engine that drives the PRL/RIIC dehullers should be equipped with a clutch so that it can be started even when the dehullers are filled with grain. Unnecessary complexity and maintenance costs may be introduced by electric starting systems for the diesel engines. Electric starters were used in some of the test sites but were subsequently removed because of the problems encountered.

Virtually all the materials and equipment for the continuous-flow mill can be manufactured or purchased in most Third World countries. Suitable hammer mills, diesel engines, baggers, sealers, compressors, generators, and spare parts are available world-wide. Detailed engineering drawings are available from IDRC for the PRL/RIIC dehuller if in-country manufacture is desirable. Alternatively, IDRC can provide the names and addresses of manufacturers in Botswana and in Canada who are able to produce and ship assembled PRL/RIIC dehullers. Furthermore, the same manufacturer in Canada is able to

Table 1. Equipment list and estimated costs for a continuous-flow mill with a PRL/RIIC dehuller and with a throughput of approximately 5 t of grain/day (one 8-hour shift/day) (in 1979 $U.S.).[a]

Item	Quantity	Description	Estimated cost ($U.S.)
PRL/RIIC	2	PRL/RIIC dehuller complete with aspirating fan	8600
Hammer mill	1	Jacobson #195 Pulverator, complete with screens, fan	7000
Diesel engine	2	Lister type 20–25 hp, 1500 rpm, hand crank, complete with clutch	9200
Auto-weigher	1	Electro-pneumatic weigher 2-kg units, 220 V, 50 Hz	3800
Heat sealer	1	220 V heat sealer	400
Generator	1	8000 watts, 220 V, 50 Hz, single phase, belt driven	1700
Air compressor	1	220 V motor-driven air compressor, with reservoir to suit auto-weigher	500
Spare parts	—	Line shafts, belts, pulleys, nuts, bolts, belt guards, etc.	1800
Drives, piping, cooling system, stands, Y valve, and cyclones			15000
Tools and equipment	—	Ammeter, voltmeter, welding equipment, fire extinguishers, pushcart, tachometer, bearing puller, clamps, etc.	2000
Total			50000

[a]Additional costs would include taxes; shipping and administration costs; installation costs; building; land; fuel tanks; sewing machines (optional for cotton-bag packaging); packaging materials; vehicle (optional); other tools; grain (minimum of several months supply); and other operating requirements.

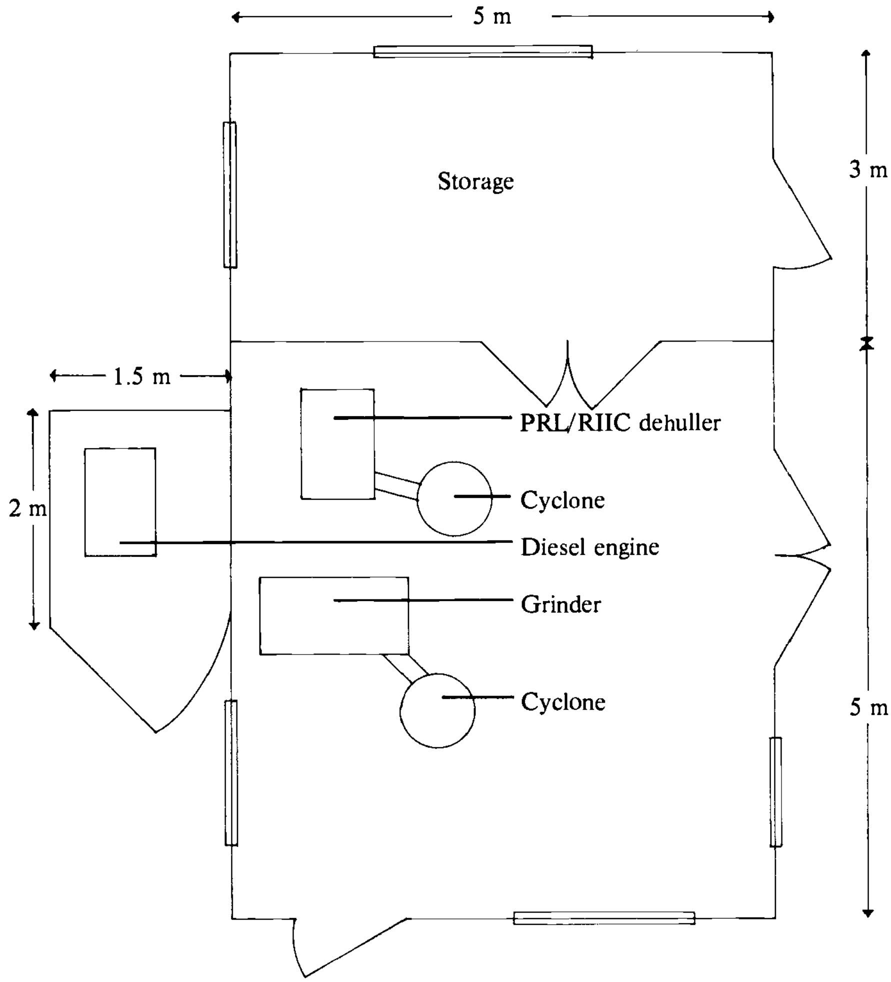

Fig. 4. Sample floor plan for a service mill.

supply the entire assembled milling unit including the PRL/RIIC dehullers, grinder, auto-weigher, and so forth.[7]

It must be emphasized once again that the recommended equipment line depicted in Fig. 3 and described above is not the only combination of equipment and models that will yield an acceptable product. However, this combination of equipment has been tested repeatedly and has proved to be successful.

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[7]For detailed engineering drawings of the PRL/RIIC dehuller and the names and addresses of various manufacturers, contact: IDRC, Postproduction Systems, Suite 304, 10454 Whyte Avenue, Edmonton, Alta., Canada T6E 4Z7.

Table 2. Equipment list and estimated cost for a service mill using a PRL/RIIC dehuller and capable of processing up to 3 tonnes of grain a day (in 1979 $U.S.).[a]

Item	Quantity	Description	Estimated cost ($U.S.)
PRL/RIIC dehuller	1	PRL/RIIC dehuller complete with aspirating fan	4300
Hammer mill	1	Jacobson #160 Pulverator, complete with screens	6000
Diesel engine	1	Lister type 20–25 hp 1500 rpm, hand crank, complete with clutch	4600
Drives, piping, cooling system, stands, cyclone	—		4100
Tools and equipment	—	Hand tools, fire extinguisher, pushcarts, tachometer, bearing pullers, clamps, etc.	1000
Total			20000

[a]Additional costs include taxes; shipping and administrative costs; installation costs; building; land; fuel tanks; other tools and operating requirements; simple weighing device.

SUMMARY OF EQUIPMENT AND ESTIMATED COSTS FOR A CONTINUOUS-FLOW MILL

A summary of the suggested equipment for the continuous-flow mill along with an estimated cost is shown in Table 1. The quoted costs are approximate and are presented to provide a rough estimate of equipment costs only. Although the mill equipment represents a substantial portion of the total cost, other factors must be estimated and included before a total investment figure can be calculated (page 31).

THE SERVICE-MILLING SYSTEM

As with the continuous-flow mill, there are numerous possible building and equipment layouts for the service mill. The floor plan that was successfully used in Botswana has been sketched in Fig. 4. Because the service mill is a much simpler system than the continuous-flow mill, the building and equipment needs are much less elaborate. For example, if the mill is processing only numerous small quantities of grain, there is no need for grain or flour storage areas. However, in the layout in Fig. 4 an area has been reserved for grain and flour storage so that some contract milling for institutional customers can be undertaken.

The basic equipment needed for a service mill consists of one PRL/RIIC dehuller, one 20–25-hp, water-cooled, diesel engine, and one grinder.[8]

When operating continuously, this equipment can process up to 3000 kg of grain a day. However, when the mill operates as a batch or service mill, the output could be considerably lower because down-time increases when numerous individual customers are using the facility on any workday.

[8]The same models and types of equipment are required for a service mill as for a continuous-flow system. Consequently, the reader should refer to earlier sections for a more complete description of the various parts of the service mill.

A summary of the suggested equipment needed for the service mill along with an estimated cost is available in Table 2. As mentioned earlier, the quotes are approximate and are presented only to provide a rough guide for equipment costs. Further details on this service mill are available from IDRC or from the Rural Industries Innovation Centre in Botswana (Appendix 1).

5

PLANNING A MILL The technical success of the milling systems described in this booklet has been proved. When the mills were tested, the problems that did arise were likely the result of nonmechanical errors and oversights in initial planning. Consequently, the purpose of this chapter is to provide a general description of the steps that must be taken by persons investigating the feasibility, or planning the operation, of the milling systems. Obviously, the steps do not precisely fit all conditions, but they should be the basis of feasibility studies and operational plans.

Because the continuous-flow and service mills are quite different in their operational requirements, their planning stages are described separately.

PLANNING A CONTINUOUS-FLOW MILL

The general steps in planning and implementing a continuous-flow mill are depicted in Fig. 5 and are briefly described in the following pages.

Step 1 — Analyzing grain production and consumption patterns: A brief analysis of national grain demand and supply is advisable. There is no need for a detailed and elaborate study, but it is useful to answer such questions as: How much grain is produced in the country; how much is exported or imported (Fig. 6)? Where are the main grain-growing regions? Where is the grain stored and by whom? How is grain transported around the country, and is it moved effectively and efficiently? Is grain production increasing or decreasing, and why? Is grain consumption increasing or decreasing, and why? Where are the major areas of grain consumption? Are imported flours replacing locally grown cereals as dietary staples? And in what form is the grain consumed?

Although the questions are not exhaustive, the answers should provide a general picture of grain availability and consumption. They should reveal, for instance, whether there is sufficient grain regularly released into the commercial market to supply a sorghum flour mill or whether alternative arrangements are

Study national grain production, consumption, and movement → Select potential areas for the mill → Conduct consumer preference survey → Test suitability of grain and flour samples

↓

Select possible suppliers of expendables ← Evaluate prospective marketing outlets ← Evaluate prospective grain suppliers ← Choose a mill site

↓

Determine health, labour and import regulations → Formulate a preliminary budget → Isolate possible sources of financing → DECISION TO PRODUCE FLOUR

↙

Start up mill
Break-in trial
Begin taste-panel testing/test market/
follow-up survey
Train staff
Open mill formally

← Implementation:
Formalize financing
Purchase/lease land
Design and construct building
Order mill equipment and spares
Order expendables
Recruit staff
Purchase grain
Plan taste panels
Plan flour introduction
Plan flour marketing
Design record-keeping system

↓

Routine Operation
Check quality and acceptability
Maintain equipment
Check retail activities
Monitor labour's performance
Verify records
Check sanitation

↓

Evaluate
possible expansion

Fig. 5. Summary of the implementation of a continuous-flow, dry, mechanical flour mill using the PRL/RIIC dehuller.

SORGHUM	TONNES			
	1975/76	1976/77	1977/78	1978/79
Production				
+ Imports (minus exports)				
= Available supply				
– Livestock feed				
– Seed				
– Losses and waste				
= Net supply for food				
Net supply per person				

Fig. 6. A 4-year national food balance sheet.

necessary such as contracting producers, formally contracting marketing boards or cooperatives, or purchasing all annual mill requirements immediately after harvest when supplies are large and prices low.[9] In the short term, it may even be necessary to purchase imported sorghum for the mill, but it must be stressed that one of the major purposes of the mill is to help stimulate production of locally grown cereals and not to rely on imported grains.

At this preliminary stage, it is important to know whether sufficient grain will be available and generally what the supply sources are.

The study of grain supply and demand can be completed with little effort. Most governments collect production information and import and export data on agricultural commodities. Some universities, and particularly departments of agricultural economics, have analyzed grain movements and have studied grain-consumption patterns. Even some private agricultural businesses and parastatal companies have collected information on the agricultural sector. Consequently, visits to various institutions and libraries and interviews with individuals in government, universities, and industry will provide most of the needed information. Likely, some reports and some comments may not be totally accurate or complete, but, nevertheless, tapping a number of sources will generate a reasonably reliable assessment of grain demand, supply, and movement.

Step 2 — Selecting potential marketing territories: The information collected on grain availability and consumption is the first step toward isolating potential areas for the production and marketing of sorghum flour. For simplicity and clarity, it is suggested that the major regions of production and consumption be plotted on a country map. Likely the two areas will not coincide — most grain is grown in rural areas where population is sparse and where the market for sorghum flour would be relatively small. The consumption of sorghum is likely most pronounced in urban or semiurban areas that are usually some distance from the major producing areas.

A centralized, continuous-flow milling system should have the mill near a major centre of consumption for the following reasons:

- Grain is a more stable product than flour and can be transported more easily.
- Grain transport systems are generally better developed to deliver grain from rural areas into urban and semiurban centres.
- The market for preprocessed sorghum flour is potentially stronger in urban areas. Compared with rural regions, the population is growing more rapidly in urban areas, city dwellers usually have less free time for dehulling and grinding grain, and incomes are rising faster.

One or two potential marketing territories should be selected near an urban centre, where sorghum consumption is high and a major sorghum-producing area is nearby.

As mentioned earlier, no other mechanical systems available today are known to be commercially processing and marketing sorghum flour. Conse-

[9] It has been suggested that in regions where the amount of grain entering the formal marketing system is small, it might be wise to involve grain producers in both the planning and the managing of the mill. Then, a continuous flow of grain to the mill might be assured.

Sorghum bran (left) and sorghum flour (right) produced in the service mill.

quently, wherever preprocessed sorghum flour is introduced, it will be a new product, never seen before. Furthermore, if the mill is located adjacent to an urban centre, the output will meet only a small percentage of total sorghum-flour demand and even a smaller part of total flour demand. For these reasons, an extensive market survey is not considered necessary. Later, if sorghum-flour production is to be increased, a more elaborate and formal marketing study should be seriously considered before expansion is undertaken.

Step 3 — Consumer preference study: After one or two potential marketing territories have been selected, a simple consumer preference survey should be initiated in the selected areas to gather general information on grain and flour utilization and acquisition patterns from the people who normally use sorghum in their diets. For example, the survey would provide an indication of the potential demand for preprocessed sorghum flour, of the various quality characteristics of a preferred flour (e.g., colour, texture, particle size), of the price consumers are prepared to pay for mechanically processed sorghum flour, an acceptable package size, an estimate of the frequency of purchase and so forth. In addition, information may be collected on consumption and purchasing patterns that may help determine the best way to market the flour once production has started. Furthermore, a well-conducted survey may give potential investors more confidence in the milling enterprise and thereby facilitate the acquisition of credit.

A simple questionnaire will be needed. An example of a questionnaire that was used in Botswana is available in Appendix 2. It is essential that the survey be short, simple, and unambiguous. The questionnaire in Appendix 2 may need modifications to suit different conditions, but it asks questions that need to be answered almost anywhere a mill is being considered.

The next step is to select a sample of the potential consuming population. As a general rule, a sample of approximately 100 people is suitable, and the sample must represent the general population who will be purchasing the sorghum flour. For instance, the sample should not be restricted to people in the middle and upper economic classes. If possible, three or four streets in a city should be selected and every sixth or seventh household on each of the streets asked to participate in the survey. The survey should aim at interviewing homemakers with families because this group is usually responsible for all food preparations and would be most affected by the presence of packaged sorghum flour. It is important to remember that the target group of the survey is the sorghum-eating population.

Also at this preliminary stage, it is advisable to have discussions with officials of nearby institutions as potential customers. For example, boarding schools, universities, prisons, hospitals, and hotels may be very important customers — a regular, guaranteed market that will help smooth out any demand fluctuations.

Step 4 — Testing existing grain and flour samples: The grain varieties that are most popular in any location are likely to produce the most popular flour. However, it is important to determine whether the dehuller and grinder can be adjusted to produce a flour that approximates the quality of flour being processed locally by hand. Samples of grain and traditionally processed flour need to be collected for testing. Unfortunately, at the moment, there is no one specific laboratory where testing can be undertaken. However, for assistance in selecting a laboratory where samples can be sent, write to IDRC. Grain and flour samples should *not* be sent to IDRC. By return post, the Centre will provide names and addresses of suitable laboratories. Upon choosing a suitable laboratory, you should collect three samples each of local grain and flour:

- Flour samples. Three samples, approximately 0.5 kg each, of manually processed sorghum flour should be obtained from three different suppliers. *Each* sample should be clearly identified with information on (1) the name of sorghum variety used to produce the flour (if known); (2) date when purchased; (3) place where purchased; (4) cost per kilogram; (5) name of buyer; and (6) address of buyer.
- Grain samples. Approximately 2 kg (maximum), each, of the three most popular varieties of sorghum should be purchased in the local market. Again, *each* sample should be clearly identified with information on (1) variety name (if known); (2) place where purchased; (3) date purchased; (4) cost per kilogram; (5) name of buyer; and (6) address of buyer. Further labeling, handling, packaging, and shipping instructions will be supplied by the laboratory.

Step 5 — Assessing prospective grain suppliers: When the market territory for flour and the appropriate varieties of sorghum have been selected, it is necessary to gather more details on who will supply the needed grain. At this stage, no formal agreements should be made with suppliers, but it is important to evaluate the different sources for grain. Visits should be made to grain wholesalers, to cooperatives, to marketing boards, to state farms, and to any other individuals or businesses known to sell grain in quantity. During each visit, the supplier should be rated on the basis of:

- Quantity. For simplicity, it is preferable to have two or three relatively large suppliers than to have numerous small suppliers, and an assessment should be made of the quantity of grain that each supplier can guarantee to deliver to the mill.
- Delivery schedule. Depending on the supplier's method of operation, it may be necessary to ascertain whether a theoretical delivery schedule can be met.

If the mill cannot be continuously supplied with grain, the profitability of the entire operation is in jeopardy.

• Transportation. Coordinating the transport of grain to the mill is both costly and time-consuming. It is recommended that the prospective suppliers be asked to deliver grain directly to the mill or to a nearby storage facility even if it means slightly higher cost to the mill. Suppliers should be evaluated on their ability to provide transport.

• Price. The largest single cost in the mill operation is the grain. Obviously, it is crucial to negotiate the best possible price to improve the profitability of the mill.

• Quality. Suppliers should be made aware of the quality of sorghum needed in the mill. Most quality standards can be visually checked -- the only exception being moisture content. Any grains not meeting the following quality standards should not be accepted: (1) The moisture content recommended by the Ministry of Agriculture for stored grain should be adopted as a standard for grain purchases for the mill. A moisture meter will have to be obtained. (2) Grain that is seriously damaged by insects will reduce the dehulling efficiency of the mill and will result in a poorer quality flour. Therefore, grain that shows serious insect damage should not be accepted for processing. (3) Grain that shows no damage by insects may have been treated with a chemical pesticide and could be quite harmful if eaten. Consequently, grain that has absolutely no insect damage or presence should be isolated and inspected for pesticides before being accepted for processing. (4) Unless the mill is equipped with a precleaner, grain with substantial amounts of dirt, stones, or other foreign matter should not be accepted. (5) And for a uniform product, the grain should be homogeneous. Any sack of grain that contains many different-coloured kernels should not be accepted.

• Variety. Because some varieties of sorghum produce better flour than others, suppliers should be evaluated on their ability to distinguish between different varieties. Once the preferred varieties have been identified through laboratory testing, the supplier(s) can be notified of the type required.

In summary, potential suppliers should be assessed on their apparent ability to deliver the variety, the quality, and the quantity of grain desired on days that will guarantee a continuous flow through the mill. In addition, it is suggested that existing grain marketing systems be utilized to the maximum. There are serious disadvantages to imposing a new marketing routine if an adequate system already exists.

Step 6 — Assessing prospective flour marketing outlets: Obviously, the flour serves no purpose unless it reaches the consumers. Information should be collected on possible sales outlets. Establishing a variety of marketing outlets should be the goal so that the product reaches a wide range of consumers and so that the competition among outlets is sufficient to eliminate profiteering. Possible outlets for the flour include cooperative stores, private wholesalers, one or two supermarkets, market traders, institutional customers, and so forth. The flour marketing outlets should be assessed on their reliability, the scope of their business, their ability to meet payment deadlines, and their fairness to the consumers.

Depending on local customs, it may be necessary to licence selected buying agents after the mill has started production and after marketing outlets have been more thoroughly evaluated.

Again, no selling arrangements should be formalized at this stage. Once the decision to install a mill has been reached, the marketing outlets can be more precisely defined and selected.

Step 7 — Suppliers of expendable items: The mill will need various expendable items such as polyethylene or cotton bags, grease, diesel or petrol, etc. At this preliminary stage, the availability and delivery time for these supplies should be checked.

Step 8 — Regulations: Before any decision to produce flour is made, all health, packaging, labour, and licencing codes and regulations should be scrutinized. Because the mill is handling food products, health authorities should be contacted and all pertinent regulations clarified. In addition, because some or all of the machinery will be imported, all foreign exchange and import regulations should be studied.

Step 9 — Choosing a site for the mill: Although a final choice should not be made at this stage, some thought should be given to selecting a suitable parcel of land on which to locate the mill. One or two potential sites should be chosen, but final selection reserved until the decision to produce has actually been made.

The criteria for selecting appropriate sites are that:

- The land should be flat so that costs are minimized and building is facilitated.
- The site should be slightly away from the city so that people will be discouraged from loitering nearby.
- For hygienic reasons, a reliable and clean water supply is recommended.
- To provide good ventilation inside the mill building, the site should make use of prevailing winds.
- The site should be located so that it is accessible to prospective buyers and suppliers of fuel, spare parts, and expendables.
- Because the mill is handling food products, it should be located away from other industrial operations that produce strong odours that may flavour the flour.
- For hygienic reasons also, the mill should be located away from any serious source of bacterial or chemical contamination.
- The site should have good drainage.
- The amount of land should be sufficient to allow for future expansion.
- Depending on the procedures used to procure and deliver grain, sufficient area should be reserved for storage purposes.

Step 10 — Preparing a preliminary budget: At this stage, sufficient actual and estimated costs have been collected to form the basis for preliminary budgets for the mill. A budget simply lists the costs and returns expected from the mill under different operating assumptions. A budget has at least three uses that demand it be prepared with care:

- For appraisals of the costs, returns, and profit margins under various operating conditions and as a basis for decision-making on the most attractive (and profitable) organization for the mill;
- As a monitor of the mill while it is functioning, a means to isolate and correct problems; and
- As a means to evaluate the mill after it has been operating for some time.

There are several different methods to estimate costs, returns, and profit margins for the mill. Very elaborate procedures are possible, but, even for

Table 3. Cost estimate for the operation of a continuous-flow sorghum mill using one line of equipment and working one shift a day (in 1979 $U.S.).

Grain processed annually	1400	
Flour produced (at 75% extraction rate)	1050	
Bran produced	320	
Waste (3.5%)	30	
Capital costs		
Mill equipment (estimated cost)	50000	
Building (estimated cost)	+	
Land (estimated cost)	+	
Vehicle (optional, use actual quote)	+	
Total capital costs		
Fixed costs		
Interest (actual interest rate × investment)		
Depreciation		
Equipment (10% of estimated cost)	5000	
Building (5% of estimated cost)	+	
Land (use most common rate in country)	+	
Vehicle (33 1/3% of actual quote)	+	
Mill manager salary (use estimated salary)	+	
Mill mechanic salary (use estimated salary)	+	
Administration (use 5–10% or most common rate in country)	+	
Total fixed costs (A)		
Variable costs		
Mill labour wage (5–6 labourers × actual rate)		
Fuel (8500 litres × rate)	+	
Repairs and maintenance (estimated at 5–6%)	+	
Packaging supplies (use actual estimate for packaging desired — poly or cotton)	+	
Miscellaneous supplies (estimate 0.5–1%)	+	
Total variable cost (B)		+
Total annual costs (A + B = C) to process 1400 t grain		
Cost of processing 100 kg of grain (C ÷ 14 000)		

industries that are well-organized and that have been repeatedly analyzed, budgets are still only good approximations of what is expected. No matter what method is adopted, the costs and returns should be estimated for several different mill operations — such as for two shifts a day versus one shift a day; for different mixtures of equipment; for different building designs; for various parcels of land; for milling both sorghum and maize flour; and so forth. Only through study of various mill operations will the most attractive setup become obvious.

Because the milling system described in this booklet is a new industry and will be creating a new market, it is impossible to study past performance records as a guide to determining optimum volume, price, operating conditions, and so forth. Consequently, it is suggested that budgeting be a three-step procedure.

The first step is to calculate expected total costs and an average or unit cost of processing grain. Table 3 provides a summary of the items that must be included in cost determinations. For most items, actual quotes or estimated costs should be used. The fixed costs are those that must be met whether flour is being produced or not, and variable costs are those that accumulate only when flour is being made. From the total of fixed and variable costs, the average or unit cost of processing can be determined. The unit chosen may be 100 kg of grain for ease of calculation (Table 3), or it may be a packaging unit for the flour, such as 2.5 kg. The average cost of processing is the total cost divided by the total number of units of the chosen weight.

The second step is to determine a marketing margin — the difference between the selling price of the flour and the cost of the grain used to make the flour. A marketing margin that is sufficient to cover all costs is dependent on the cost of the grain, the extraction rate, the value of any by-products (namely bran), and the cost of processing the grain per unit (Table 4).

This marketing margin is only the break-even charge for the flour. If less than the marketing margin is used as a markup, a subsidy will be needed just to cover costs. A realistic price includes a profit margin. An acceptable profit margin may be difficult to determine particularly on a new product. However, there are two guides that may be used. One is to adopt a profit margin similar to that used on any other locally available and commercially produced flour. The other is to refer to the results of the consumer preference survey (Step 3) showing what consumers are willing to pay for packaged sorghum flour.

The final budgeting step is to calculate an expected return from several marketing and profit margins and to compare the results with several examples of estimated costs (as determined in Table 3). Planners must be certain that all the assumptions pertaining to each example of estimated costs and returns be clearly described — for example, for what time the estimate applies, how many work shifts are employed, what is being produced, etc. If the assumptions are not clearly stated, it will be impossible to compare different operating systems and to select the best.

Step 11 — Financing the mill: The investment needed to start and operate a continuous-flow mill is not excessive compared with that for many other industrial projects, but it likely exceeds the financial capability of most individuals. The mill might be a new addition to an existing business; it could be managed by a farmer-owned cooperative; or it could be established as a partly or wholly owned government enterprise. No matter what form the mill administration takes, there will be a need for capital.

Table 4. Finding the marketing margin.

Cost of grain (100 kg)	________
Minus value of by-products from 100 kg grain	- ________
Plus cost of processing 100 kg grain	+ ________
Equals cost of producing 75 kg flour (at 75% extraction rate)	________
Cost of producing 100 kg flour (cost of producing 75 kg divided by the extraction rate, e.g., 0.75)	________
Minus cost of 100 kg grain	- ________
Equals marketing margin to cover all costs associated with processing the grain	________

When the amount of capital required for the mill is being calculated, it is important to remember that funds are needed to cover not only the capital costs but also a portion of the annual operating costs as well. Some expendables and some grain will have to be purchased before any returns have been realized by the mill. Depending on local customs, it may be necessary to borrow the entire capital cost requirements plus 6–8 months' operating requirements.

If the mill is being operated under government auspices, there is little need to investigate various sources of credit. Allocations in annual ministry or department budgets should be planned and requested. If the mill is being operated under private or cooperative ownership, then various lending institutions should be approached. In most countries, government lending schemes have been established to encourage agricultural or industrial development. Such schemes usually lend funds at a subsidized interest rate. All the same, it is useful to check lending rates and repayment terms at private lending institutions in the event that preferential credit is not available from government schemes.

If the application for a loan is well-prepared, then a written "approval in principle" should be sought from the lender. At this stage there is no need to secure the loan, but it is reassuring to know that lending institutions are confident in the mill's viability.

No matter whether the mill is government or privately controlled, a comprehensive plan for the mill should be documented. It serves as a checklist for all aspects of preparations, and it will help secure credit and facilitate an evaluation after the mill has become functional. If the various steps outlined in this booklet are followed, a reasonable, methodical plan will have been completed.

Step 12 — Decision: When all the preliminary work is done and all the data are collected and analyzed, it is time to weigh objectively all factors involved in establishing and operating a continuous-flow mechanical flour mill. It is essential that the glamour of the new technology be put in perspective. The mill operation requires long hours of work and substantial amounts of planning and coordination for it to be successful.

After careful consideration, if the decision to produce flour has been reached, the next steps are to implement the plan.

Step 13 — Initial implementing period: Unfortunately, most of the steps in the early implementation require attention simultaneously. Once the decision to produce has been reached, a very busy time has started. The person(s) in charge must:

- Secure financing at the best possible rate with the most convenient repayment terms.
- Purchase or lease land at the best possible rate.
- Design the mill (and storage) building, tender contracts, begin construction, and order mill equipment and spare parts.
- Order expendable items and, specifically, order sufficient quantities of packaging bags to cover several months of operation. A design should be clearly printed on the bag that indicates what is inside. It is also suggested that the bags be identified in some manner so that poor flour can be traced back to its origin. This identification can take several forms, and it may or may not be printed on the bag itself.
- Begin to recruit mill staff (Appendix 5).
- Arrange for the purchase and delivery of grain. At the very minimum, the quantities of grain should be (1) 30 tonnes of the preferred variety as determined

from laboratory testing (Step 4) and (2) a tonne each of the other two varieties. These purchases will be used during the break-in period of the mill and during initial taste-panel testing.

- Plan for the introduction of the flour into the marketplace. Possible promotional devices that should be designed at this stage include advertisements for the newspapers, brochures, posters for display in local markets, demonstration booths, and so forth.
- Contact distributors and arrange for the introduction of the flour.
- Begin to design a record-keeping system (Appendix 6).

Step 14 — Implementation: Once the building is completed and the equipment installed, several test runs should be made with the three varieties of grain so that the optimum technical conditions for operating the system can be determined. A range of flours should be produced for testing by the taste panel and by others in a follow-up survey.

The taste panels and follow-up surveys help to ensure that the flour satisfies consumers' requirements. Several people who regularly eat sorghum should be selected to participate in the taste trials of flour produced from the three varieties of grain. The participants should be asked to rate the mechanically processed flours on the basis of colour and texture. With the results from the taste panel, the equipment should be adjusted to produce the preferred type of flour and a follow-up acceptance survey conducted. Both the taste panel and the follow-up survey may be done with the assistance of the families interviewed earlier (Step 3). An example of a follow-up survey is available in Appendix 3.

After the follow-up acceptance survey, full-scale production can begin. A quality standard should be set and adhered to so that a homogeneous product is ensured. The standard can be simply a visual comparison with the preferred flour selected by the taste panel and tested in the follow-up survey.

It must be stressed, once again, that for the mill to attain maximum profitability, it must operate continuously. Any work stoppage reduces the mill's financial viability. Consequently, staff must be thoroughly trained. Each employee must be fully aware of his or her responsibilities. In some work situations, it may be useful to introduce a profit-share scheme with the labourers — it may provide more incentive to produce a good quality product at maximum output.

The mill should be operated as autonomously as possible. If the mill is part of a larger enterprise or managed by government, the mill manager must be given sufficient authority to make decisions on the spot.

As soon as the mill is producing a good quality product with no disruption in output, it might be wise to have a formal opening ceremony to which local dignitaries have been invited. This event will provide media exposure at no cost and will thereby let consumers know that prepackaged sorghum flour is available.

Step 15 — Routine day-to-day operations: As soon as the mill is running smoothly and a good quality product is available, there are several routine procedures that should be anticipated. They include continual checks on the quality of grain and flour; on the acceptability of flour by consumers; on the maintenance of equipment; on the selling price at the retail level; on the labourers' performance; on the inventories (ordering well in advance); on possible problems as revealed in records; on the integrity of financial and production records; and on sanitation (dealing with food products means that cleanliness and hygiene must be closely scrutinized).

It is always a good management practice to maintain amicable working relationships with mill workers, with suppliers, with flour distributors, and, wherever possible, with consumers. They are usually the first people to recognize problems with the product and with the method of operation.

Step 16 — Future operations: It is strongly recommended that an extensive evaluation be undertaken after 9–12 months of continuous operation. Every aspect of the mill's operation should be studied. Once again, most problems with the mill or with the flour are known by the mill workers or by the flour consumers.

Depending on the outcome of the evaluation, it may be wise to consider either expanding to another city or simply adding another work shift. However, if expansion is being considered, it is strongly recommended that a more extensive and formal market study be conducted.

PLANNING A SERVICE MILL

Most of the planning steps that are listed for a continuous-flow facility also apply to a service mill. Obviously, some of the steps are not needed or are unnecessarily complex when applied to a service mill.[10] The reader will be referred back to the earlier sections — only the less obvious and more critical steps of service-mill planning will be discussed here.

Step 1 — Grain production and consumption: The analysis needed for a service mill is much simpler than that required for a continuous-flow mill. The two major questions that need to be answered are: Where are the main sorghum-growing areas? And are there enough sorghum consumers in these areas to support a service mill? Almost without exception, wherever sorghum is grown in semi-arid regions of Africa, it will also be consumed in substantial quantities. However, if the mill is operating only on a service basis, sufficient numbers of people must be nearby for the mill to operate profitably. It is for this reason that some basic consumption-per-capita data should be collected and analyzed.

It might also be useful to determine whether producers are increasing, decreasing, or maintaining their output in the major producing areas. If there is a pronounced shift away from sorghum and into cash crops, it may be wise to locate a service mill in a community that has consistently produced large quantities of sorghum and other cereals.

Step 2 — Selecting a milling territory: The information collected on grain production and population (consumption) should pinpoint a potential milling territory. A milling territory should be a location where sorghum production is concentrated and where 2000–3000 people (who regularly eat sorghum) live within a 15-kilometre radius. Naturally, the number of people needed to support a service mill is extremely variable and is dependent on factors such as the level of per-capita consumption, how much each mill customer will process each visit, how much is charged for dehulling and grinding, and whether or not any contract milling is being planned. An ideal milling territory would be in a

[10]Whenever a combination of service and continuous-flow systems is being anticipated, a more rigorous planning phase is required than is needed for a service mill.

moderately sized village adjacent to an important sorghum-growing area — particularly if one or two institutional customers are nearby.[11]

The importance of nearby institutions should be stressed. Because mechanical dehulling is an innovation, it may take some time for individual customers to accept and use the new technology. Consequently, it is suggested that contract milling for institutional customers be planned from the start. Then, any milling capacity that is not utilized for service milling can be devoted to meeting the demand for flour from institutional customers.

Step 3 — Mill utilization survey: In the selected milling territory, a simple survey should be conducted to determine whether homemakers are willing to use a mechanical dehulling and grinding facility. In addition to determining the potential demand for service milling, the survey would provide an indication of the preferred quality characteristics of dehulled cereal and flour and the price people are willing to pay for the processing service. An example of a simple questionnaire is found in Appendix 4. A sample of approximately 40–50 households should be surveyed, and, once again, it is essential that the sample represent the general sorghum-consuming population.

At the same time, possible institutional customers should be visited so that their interest in purchasing sorghum flour in bulk can be investigated.

Step 4 — Testing existing grain and flour samples: As discussed earlier, it is important to ascertain whether the PRL/RIIC dehuller is capable of producing the quality of flour that is processed by hand. Consequently, samples of common grain varieties and acceptable flours should be collected (page 29).

Step 5 — Regulations: Because the service mill is handling food products, all relevant regulations suggested on page 31 should be studied.

Step 6 — Choosing a site for the mill: Within a milling territory, a potential site for the mill should conform to the criteria outlined on page 31. However, the most important factor is to choose a site that is accessible. Obviously, if the mill is situated in a remote area, far from family compounds, it will be quite difficult to attract customers. The mill must be located on a site that is accessible to homemakers year round — not just during the wet or the dry season.

Step 7 — Preparing a preliminary budget: A preliminary budget for a service mill should be prepared as outlined on pages 31-33. However, because a service mill is a much simpler operation than a continuous-flow mill, many of the suggestions discussed earlier do not apply. For example, the amount of equipment needed for a service mill is much less than that needed for a continuous-flow system, and the cost associated with mill equipment in the budget should reflect the estimates given on page 23.

As described earlier, the first step is to calculate expected total cost and the average or unit cost of processing grain. Table 5 provides a summary of the items that should be assessed. In determinations of the amount of grain processed annually, the estimates provided in the mill utilization summary (Appendix 4) should be considered.

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[11] Locating a service mill in or near a large urban centre should not be discounted. In many urban areas of the Third World, sorghum is a preferred cereal, and manual processing is commonplace. Some customers may prefer to buy grain and bring it to a service mill for processing. An urban location is also advantageous because it would be quite easy to capture institutional customers and to provide a contract milling service.

Whereas in a continuous-flow mill the next step is to calculate a marketing margin, in a service mill operation, where flour is not being sold, the average or unit cost of processing is the cost that must be covered — the break-even charge. If the customer is charged less than the cost of processing, then the operation will lose money. A small profit margin should be added to the cost of processing, and it is suggested that only a modest margin be included so that full use of the mill will be encouraged.

The final step is to calculate and compare expected costs and returns with various operational setups and several profit margins. Once again, when assessing different types of operations, planners must be certain that all the assumptions pertaining to each example of estimated costs and returns be clearly described so that it is possible to compare different systems and to select the best.

Table 5. Cost estimate for the operation of a sorghum service mill (in 1979 $U.S.).

Grain processed annually (use estimate from mill utilization survey)	______ t	
Capital costs[a]		
Mill equipment (estimated cost)	20000	
Building (estimated cost)	+ ______	
Land (estimated cost)	+ ______	
Total capital costs	______	
Fixed costs[b]		
Interest (actual interest rate × investment)	______	
Depreciation		
Equipment (10% of estimated cost)	+ 2000	
Building (5% of estimated cost)	+ ______	
Land (use most common rate in country)	+ ______	
Mill manager salary (use estimated salary)	+ ______	
Total fixed costs (A)	______	______
Variable costs		
Mill labour wage (1–2 labourers × actual rate)	______	
Fuel (4000 litres × rate)	______	
Repairs and maintenance (estimated at 5–6%)	______	
Miscellaneous supplies (0.5–1.0%)	______	
Total variable cost (B)	______	+ ______
Total annual variable and fixed costs (A + B = C)		______
Cost of processing 100 kg of grain (C divided by estimate of "grain processed annually" × 100)		______

[a]In a service mill there is likely no need for a vehicle, so the cost has not been included.

[b]It is assumed that the mill manager will have some mechanical skills, and consequently a mill mechanic salary has not been included. In addition, because the service mill has relatively few pieces of equipment, a mill mechanic is probably not needed; a mechanic can be hired when needed. Furthermore, because there is very little administration required in a service mill, no administration cost has been included.

Step 8 — Financing the service mill: The procedures for financing a service mill are similar to those for a continuous-flow mill (page 33). A fundamental difference between the two, however, is that the service mill requires a smaller investment — one that might be attractive to small community groups or local cooperatives. Extensive outside financial backing may not be necessary. For example, in a service mill there is little need for funds to cover operating costs because no inventories are needed; funds will flow back into the mill operation as soon as processing begins.

Step 9 — Decision to process: As outlined previously, the next step is to assess all the considerations and all the information that has been collected.

Step 10 — Initial implementation: The procedures required to start up a service mill are similar to, but much simpler than, those described for the continuous-flow mill (page 34). Many of the steps, mentioned earlier, will not require the same attention. For example, there is no need to select grain supply agents unless contract milling is planned as an important part of the operation; marketing outlets do not need to be organized; mill staff can be reduced to one or two people; only a few expendables have to be ordered; a record system is needed but it need not be elaborate because there is very little stock control and there are very few different kinds of cash transactions and so forth. Likely the most important step during initial implementation is to plan for the introduction of the mill into the community. A service mill can only function with good community support.

Step 11 — Implementation: Implementing a service mill should proceed in the same way as implementing a continuous-flow mill. The most important step, as was already mentioned, is introducing the facilities into the community. The potential users must be made aware that the mill exists and what it is capable of doing. People should be encouraged to visit the mill (even during construction), to view the equipment, and to see how the mill operates. Meetings and demonstration booths might be planned at or away from the mill site even before the mill begins to function. Such meetings might be scheduled so that they coincide with local clinics or other community activities. In addition, agriculture, community, and health extension agents should be encouraged to inform their respective audiences about the mill and to distribute small samples of dehulled grain and flour from the mill. In summary, the mill must be well-advertised in the community.

A formal opening ceremony should be planned. At the ceremony, as well as at any of the earlier meetings, it is important that the customers be made fully aware of the terms and conditions under which the mill operates — for instance, they should know that they are required to supply their own grain and must bring two containers (one for the flour and one for the bran); they should know that the mill operates (preferably) on a cash basis only; they should be told that the grain must be well-threshed and free from foreign matter if they expect a good quality flour; and so forth.

At the opening ceremony, samples of sorghum grain, dehulled cereal, bran, and flour should be on display. The mechanically processed flour should be used in some traditional dishes, and people should be encouraged to taste them. To further interest in the facilities, the mill operators might offer service milling free of charge for the first few days.

Step 12 — Routine operations: Routine procedures for a service mill are similar to, but simpler than, those for a continuous-flow mill. The most important task is to consult regularly with customers for their assessment of flour quality.

As suggested for the continuous-flow mill, a full-scale evaluation should be planned after 9–12 months of operation. From the experience gained with the first mill, other mills might be planned in other regions where sorghum production is concentrated and where consumption is popular.

6

EVALUATING THE SYSTEMS Even though there have been several attempts to design a dry mechanical milling system that is capable of producing an acceptable sorghum flour, the mills described in this booklet are the only ones known to be commercially producing sorghum flour. Consequently, in assessments of the advantages and disadvantages of the mills, the only possible comparison today is with the traditional processing methods. In this chapter the merits and disadvantages of the two milling systems are discussed and compared with those of traditional milling on the basis of several broad criteria.

Degree of complexity and maintenance requirements: Obviously, the mills described in this booklet are more complex and demand more maintenance than any traditional manual method. However, compared with other mechanical milling technologies (e.g., roller milling), the systems using the PRL/RIIC dehuller are extremely simple and easy to maintain. Virtually anybody who is experienced and competent in the care of automobiles or small machinery can easily maintain and repair any equipment described in this booklet.

A service mill is clearly less complex than a continuous-flow mill, and the maintenance requirements are correspondingly simpler. For example, relatively sophisticated auto-weighing and packaging devices are not required in a service mill because people bring their own grain and take back their flour in the same container.

Cost: Mechanical milling accounts for higher direct costs than does any traditional method. However, traditional processing is extremely time-consuming and labour-intensive. There is a cost associated with earnings that are missed because of the time needed to dehull and grind grain manually. For example, if women devote a few hours each day to preparing sorghum flour, this time is not available for other income-earning purposes such as raising poultry, growing vegetables, making handicrafts, or joining the regular labour force. As mentioned earlier, there are also substantial indirect costs associated with traditional processing, or rather with the lack of a commercially viable mechanical system. For example, when manual processing does not satisfy the demand for sorghum flour, there is a tremendous cost associated with importation of processed flour that results in even greater costs when incentives to produce local grains deteriorate.

The direct capital investment required to establish a continuous-flow mill is much higher than that for a service mill. For example, in a service mill, building costs are lower because no grain or flour storage facilities are needed; operational costs are also lower because fewer labourers and expendable items (e.g., polyethylene or cotton bags) are needed.

Dehulling efficiency: The easiest way to determine dehulling efficiency is to calculate the amount of dehulled grain as a percentage of the amount of whole grain before dehulling was done. The result is the extraction rate, which shows how much of the kernel remains after the hull has been removed. In several unpublished studies, it has been reported that traditional dehulling techniques have an extraction rate averaging 70%. Under field conditions, the PRL/RIIC dehuller has an extraction rate averaging more than 75% (it ranges between 75% and 85%).[12] Mechanical dehulling using the PRL/RIIC dehuller under either service or continuous-flow systems tends to leave slightly more of the grain for consumption than does manual processing.

Throughput: The quantity of grain that can be processed to flour daily with either a continuous-flow or a service mill is much greater than is possible with any manual method. For example, 10 labourers producing flour by hand can probably process approximately 100 kg of sorghum a day, whereas the same number, which is more than is necessary, working in a continuous-flow mill can produce approximately 4000–5000 kg of sorghum flour a day. However, the throughput of the mill fluctuates depending on the variety of grain being processed, the fineness of flour desired, and the amount of hull removed. Furthermore, output is slightly lower when bird-resistant or hard seed-coat varieties are milled. The throughput is also lower if the mill is functioning as a service or batch operation simply because it takes time to empty and recharge the dehuller for each customer. Throughput in a service mill may also be reduced if the demand for its use is not consistent and continuous.

Nutritional value: Any cereal-processing technique, whether manual or mechanical, causes some loss of nutrients in the grain. Tests done to compare the nutritional value of grains processed manually with that of grains processed with the PRL/RIIC dehuller show that more nutrients are lost during the mechanical process. Apparently, the reason for this phenomenon is that the traditional wet process removes very little of the seed germ, which contains many of the high quality nutrients. In contrast, mechanical processing removes more of the seed germ and results in flour that has, on average, 25% less fat, 10% less crude fibre, 15% less ash, and slightly less protein than does manually processed sorghum flour. Once again, it is important to remember that the range in nutrient loss is dependent on the variety of grain used and on the conditions under which the dehuller is operating.

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[12]The extraction rate is dependent on a number of variables. For example, if the cereal is retained in the dehuller for a longer time, the extraction rate decreases.

Shelf-life: Flour that has been processed by the traditional wet method has a very short shelf-life. It becomes mouldy within a day or so after pounding and is also apt to go rancid because of its relatively high fat content. In contrast, dry processing with the PRL/RIIC dehuller results in a shelf-life of at least 3 weeks.

It must be mentioned, however, that if dehulled grain is taken from the dehuller and then ground in the traditional wet manner, the resulting flour will have a much shorter shelf-life than dry, mechanically ground flour.

Consumer acceptability: In developing countries, the fact that people are willing to spend money to purchase flour that could be produced at home from raw grain suggests that the product is both desirable and acceptable. Without exception, wherever sorghum flour has been produced by the milling systems described in this booklet, the demand has exceeded the ability to produce. The mills are sufficiently adaptable to produce a variety of flours that favourably compete both with imported flours and with flours that are processed by traditional methods.

Sociological implications: The introduction of a new product into many of the traditional societies found throughout the semi-arid regions of the world is likely to have some sociological side effects. These effects are most pronounced when the new product is food-related and particularly when the food is a dietary staple. The effect of introducing a mechanical milling system into a community can range from being totally insignificant to being moderately disruptive and from being strongly advantageous to moderately detrimental. The consequences of mechanical milling on a society are dependent on the nature and structure of the society and on how the milled product or system is introduced. It is important to remember that the process described in this booklet has not proved harmful in any of the communities where it has been tested. The system is adaptable and can be made compatible with a wide range of societies.

Mill planners must recognize that mechanical milling is apt to cause some changes in a society. For example, in many rural communities, much of the social interchange revolves around routine household tasks such as dehulling and grinding cereal. A continuous-flow system may remove this focus for community socializing, whereas a service mill still provides the opportunity for social interchanges. In addition, if a continuous-flow mill is functioning with full community support, the local economy is based on trust — trust that the grain that is sold now will be available later in the form of flour. Service processing does not require the same degree of performance from or confidence in the mill and in the marketplace. In summary, it is important to recognize and anticipate some of the sociological changes that may result from mechanical milling —changes that traditional milling will not offer or cause.

Employment generation: A continuous-flow milling system is more apt to generate new employment opportunities than is either a service mill or traditional processing. For example, if a continuous-flow mill supplied ample quantities of flour, it might encourage new secondary processing enterprises, such as those that produce composite flours, snack foods, and so forth. Also, various cottage industries might evolve if flour production were no longer a household chore. Service milling does not have as great a potential for employment generation as does the continuous-flow system, but it is capable of encouraging some secondary processing and does give homemakers much more time for other income-earning ventures.

In summary, traditional processing has not proved to be an employment-generating device except on a very small scale. In contrast, continuous-flow and service milling systems have considerable potential for the creation of new jobs and enterprises.

Management skills: The management skills needed to operate a continuous-flow mill effectively are significantly greater than those required for traditional processing and moderately greater than those required for a service mill. In a continuous-flow operation, skills are needed to coordinate the delivery of grain, the marketing of flour, the supply of various expendables, the supervision of staff, the recording of inputs and outputs, and the continuous assessment of the mill's viability. To reiterate: for a continuous-flow mill to attain maximum profitability, it must operate without disruption and, hence, demands continuous and effective management and planning.

Skills needed to operate a service mill effectively are notably fewer than those required for a continuous-flow system. For instance, a service mill requires little or no stock control; requires no monitoring of flour-marketing channels; requires fewer skills in labour management; requires only modest bookkeeping and accounting abilities; and so forth.

Degree of local support: Because traditional milling is an individual household responsibility, little or no community support is required to complete the task. In service milling, the onus is placed directly on the community to supply grain to the mill. A continuous-flow operation has other supply options that are not available to a service mill such as transporting surplus grain from other regions of the country and purchasing it in bulk immediately after harvest. Local support is crucial if the service mill is to operate effectively and profitably.

Flexibility: On the surface, traditional processing appears to have an enormous amount of flexibility as to when and how much grain is processed. However, because sorghum is a staple food in most semi-arid regions of Africa, there is, in effect, very little flexibility. Flour must be produced if the household is to eat. Several hours almost every day must be reserved for flour production. A continuous-flow mill has a certain degree of flexibility, but the service mill is much more adaptable. A service mill is capable of operating a batch system, a continuous-flow system, or a combination of the two.

Self-reliance: Traditional processing is the ultimate, albeit extremely laborious, model of self-reliance and self-sufficiency, but a local service mill may also encourage community self-reliance. The continuous-flow operation requires a larger marketing area and a substantially higher investment than does a service mill and thus may be out of reach for a rural community. However, a service mill may be quite attractive to many community groups or small, village-based cooperatives.

In summary, there are distinct advantages and some disadvantages to mechanical milling. Appendix 7 contains a comparison chart that outlines the pros and cons of traditional versus the two mechanical processing methods. Each situation must be assessed on its own merits before a decision is made either to install a service or continuous-flow mill or to maintain the traditional processing methods.

APPENDIX 1. RESOURCES

The following people have provided information used in this booklet and are valuable resource personnel:

Birinyi, G. Ackroyd Construction (1965) Ltd, Toronto, Canada.

Clarke, A. Agricultural Engineer, Consultant, Edmonton, Canada.

Eastman, P. Agricultural Consultant, Toronto, Canada.

Eisner, N. Rural Industries Promotions, Kanye, Botswana.

Fawcett, B. Agricultural Economist, Consultant, Guelph, Canada.

Forrest, R. Associate Director, IDRC, Edmonton, Canada.

Henry, S. Home Economics Consultant, Toronto, Canada.

Keay, R. Agricultural Economist, Consultant, Regina, Canada.

Lorer, E.K. Formerly at Prairie Regional Laboratory, Saskatoon, Canada.

MacFarlane, C. Rural Industries Promotions, Kanye, Botswana.

Oomah, D. Prairie Regional Laboratory, Saskatoon, Canada.

Petersen, A. Department of Rural Economy, University of Alberta, Edmonton, Canada.

Reichert, R. Prairie Regional Laboratory, Saskatoon, Canada.

Rolston, W. Agricultural Economist, Consultant, Ottawa, Canada.

Vogel, S. Program Officer, IDRC, Edmonton, Canada.

Yaciuk, G. Program Officer, IDRC, Edmonton, Canada.

Youngs, C.G. Prairie Regional Laboratory, Saskatoon, Canada.

Possible equipment suppliers include:

Kason Centri-Sifter
Separator Engineering Ltd, 810 Ellingham Street, Pointe-Claire, Quebec, Canada.

Jacobson Pulverator
Jacobson Machine Works Inc., 2445 Nevada Avenue North, Minneapolis, Minnesota, U.S.A.

Lister Diesel
Canadian Lister-Blackstone Ltd, 56 Chauncey Avenue, Toronto, Ontario, Canada.

Cyclone, Fan, Cleaner
Simon-Day Ltd, Box 488, Winnipeg, Manitoba, Canada.

Bagger

Hauser Machinery Ltd, Packaging Equipment, 45 Nantucket Blvd, Scarborough, Ontario, Canada.

Packaging Equipment Service Ltd, 1997 Leslie Street, Don Mills, Ontario, Canada.

PRL/RIIC Dehuller

IDRC, Postproduction Systems, Suite 304, 10454 Whyte Avenue, Edmonton, Alberta, Canada.

Rural Industries Innovation Centre, Rural Industries Promotions, Tsholetsa House, PO Box 18, Gaborone, Botswana.

APPENDIX 2. EXAMPLE OF CONSUMER PREFERENCE SURVEY

The main purpose of the survey is to determine whether there is a potential market for mechanically processed sorghum flour. Therefore, all questions in the survey should be aimed at fulfilling this purpose only.

Much of the following questionnaire was used in Botswana. In other locations some questions may have to be modified, added, or removed.

QUESTIONNAIRE

Date: ____________________ Location: (address)

Name of interviewer: ____________________

Good afternoon. I am ____________________ of the ____________________.

We are doing a study on sorghum, and I wonder whether you would be willing to help us by answering a few questions.

1. May I have your name? ____________________
2. Do you do most of the cooking for your family?
   Yes________ No________
   IF THE RESPONSE TO QUESTION 2 IS NO, ASK TO TALK TO THE PERSON WHO DOES MOST OF THE COOKING.
3. Does your family eat sorghum? Yes________ No________
   IF THE RESPONSE TO QUESTION 3 IS NO, GO TO QUESTION 11.
4. About how often does your family eat sorghum?
   a. Daily b. 2 or 3 times a week c. 2 or 3 times a month
   d. other
5. About how many of these (SHOW A COMMON MEASURE) would your family eat in 1 week?________
6. Where do you get most of your sorghum?
   a. Grown by family
   b. Purchased from friends
   c. Purchased from the village market, trader, or shop
   d. Purchased from co-op, marketing board. Name it: ____________________
   e. Other. Explain: ____________________
7. What do you most often prepare from sorghum flour? (LIST THE MOST COMMON DISH AND ANY OTHERS THAT ARE GIVEN AS BEING IMPORTANT.)
   a.
   b.
   c.
8. If you make your own flour, which of these sorghums do you prefer to use? (SHOW 5 OR SO COMMON VARIETIES.)

Don't make own flour	A	B	C	D	E	None of them

9. Which colour of sorghum flour do you like (three samples)?

Red:	best	second-best	least
Brown:	best	second-best	least
White:	best	second-best	least

No strong preference__________

Don't know __________

None of these samples __________ Why __________

10. Which of these flours do you like (three samples of flour all the same colour but different textures)?

Fine	best	second-best	least
Medium	best	second-best	least
Coarse	best	second-best	least

No strong preference__________

Don't know __________

None of these samples __________ Why__________

11. Do you think it is a good idea to have sorghum flour that has been produced by a machine?

Yes__________No__________Why__________

12. What size bag of sorghum flour would you like to buy?

Less than 2 kg_______ 2-5 kg ________ 5-10 kg ____

More than 10 kg_____ Don't know_____ Other______

Would not like to buy__________ (GO TO QUESTION 16)

13. For the size of package you would most like to purchase, how much would you pay?__________

14. How often would you buy this size bag of flour?

__________bags of__________kg a week

15. What size bag of sorghum flour would you not like to buy?__________

16. If we gave you some sorghum flour (or dehulled sorghum), which was produced by a machine, would you be willing to try it in your home for a week or so?

Yes__________No__________

Thank you very much for your help.

APPENDIX 3. EXAMPLE OF FLOUR ACCEPTANCE SURVEY

To help determine whether the flour produced in the mill(s) is acceptable to consumers, a simple survey can be conducted as a follow-up to the consumer acceptance survey (Appendix 2) and the mill utilization survey (Appendix 4). The last question on these two surveys asked whether the respondent would try mechanically processed flour in the home for a week. Some of the people who answered "yes" should be given flour that has been mechanically processed. After they have used the flour for about a week, they should be asked to assess the flour. An example of a questionnaire is given below. This procedure can be used at *any* time during the mill operation to assess the quality of the flour being produced.

QUESTIONNAIRE

Date: ____________________ Location: ________________
(address)

Name of interviewer: ____

Name of interviewee: ____

Good afternoon. Some time ago I asked you several questions about sorghum. At that time, I asked whether you would be willing to use some sorghum flour in your home, and you said yes. Here is a bag of sorghum flour for you to try. We would like you to use it in the normal way. Would you be willing to do this?

Yes__________No__________ (RECORD AS A NONPARTICIPANT)

I will be back to talk to you in about a week.

1 WEEK LATER

1. Have you had a chance to use the flour that was left?
   Yes__________No__________
   IF "NO" ASK THE FOLLOWING TWO QUESTIONS ONLY.
   IF YES, GO TO QUESTION 2.
   I. When might you try the flour? ______________________________
   II. Would it be all right if I return on (date) ______________________
   Yes__________No__________
2. Taking everything into consideration, how would you rate this flour?
   a. Excellent
   b. Extremely good
   c. Very good
   d. Quite good
   e. Fairly good
   f. Fair
   g. Poor

3. What did you like most about the flour?
4. What did you like least about the flour?
5. Would you say the flour was:
   a. Easy to use b. Neither easy nor difficult c. Difficult to use
6. How did the foods made from this flour compare with the foods made from sorghum flour you normally use?
   a. Superior
   b. Equal to
   c. Inferior
7. What would you consider to be a fair price for this flour in a bag the size you had?
   ________per________kg
8. If you supplied your own grain, how much would you pay to have it processed into flour?
   ________per________kg
9. (THIS QUESTION SHOULD BE WORDED TO REFLECT WHETHER A SERVICE OR CONTINUOUS-FLOW MILL IS BEING PLANNED.) Which of the following statements would best describe your likelihood of (buying this flour if it were sold at________) (processing your grain if it cost ________):
   a. I would definitely (buy) (process)
   b. I would very likely (buy) (process)
   c. I might or might not (buy) (process)
   d. I am not likely to (buy) (process)
   e. I definitely would not (buy) (process)
10. Do you have any other comments that might be helpful to us?

Thank you very much for your helpful comments.

APPENDIX 4: EXAMPLE OF VILLAGE MILL UTILIZATION SURVEY

The main purpose of the survey is to determine whether there is a market for a mechanical sorghum processing facility. Therefore, all questions in the survey should be aimed at fulfilling this purpose. In different locations, some questions may have to be changed, added, or removed.

QUESTIONNAIRE

Date: ____________________ Location: ____________________
(address)

Name of interviewer: ____________________

Good afternoon. I am ____________________ of the ____________________

We are doing a study on sorghum and I wonder whether you would be willing to help us by answering a few questions.

1. May I have your name? ____________________
2. Do you do most of the cooking for your family? Yes________ No________
   IF THE RESPONSE TO QUESTION 2 IS NO, ASK TO TALK TO THE PERSON WHO DOES MOST OF THE COOKING.
3. Does your family eat sorghum? Yes________ No________
   IF THE RESPONSE TO QUESTION 3 IS NO, GO TO QUESTION 9.
4. About how often does your family eat sorghum?
   a. Daily b. 2 or 3 times a week c. 2 or 3 times a month
5. About how many of these (SHOW A COMMON MEASURE) would your family eat in 1 week?________
6. Where do you get most of your sorghum?
   a. Grown by family
   b. Purchased from friends
   c. Purchased from village market, trader, or shop
   d. Purchased from co-op, marketing board. Name it: ____________
   e. Other. Explain: ____________________
7. What do you most often prepare from sorghum flour? (LIST THE MOST COMMON DISH AND ANY OTHERS THAT ARE GIVEN AS BEING IMPORTANT)
   a.
   b.
   c.
8. Which of these flours do you like (three samples of flour, all the same colour but different textures)

Fine:	best	second-best	least
Medium:	best	second-best	least
Coarse:	best	second-best	least

No strong preference________
Don't know ________
None of these samples________ Why ____________________

9. Do you think it is a good idea to have a machine that will produce sorghum flour?
   Yes__________No__________Why______________________________
10. If a flour-making machine were available, would you use it?
    Yes__________No__________Why______________________________
11. If a machine were available, how much would you pay to have your sorghum turned into:
    a. Dehulled grain like this (SHOW SAMPLE)?__________per__________kg
    b. Flour like this (SHOW SAMPLE)?__________per__________kg
12. If a flour mill were to be put in this area, where do you think would be a good place to locate it? Why?
13. If we gave you some sorghum that was dehulled and ground by a machine, would you be willing to try it in your home for a week or so?
    Yes__________No__________

Thank you very much for your help.

APPENDIX 5. TERMS OF REFERENCE FOR MILL EMPLOYEES

The responsibilities and duties of each staff member should be clearly stated and understood by the employees. The performance of each employee should be monitored but in a cooperative rather than a hierarchical manner.

The mill should be organized and staffed to run autonomously, with little interference from a head office, from a government department, or from any other subsidiary operation.

The number of staff and their respective duties will vary according to local conditions. The brief job descriptions given below apply mostly to a continuous-flow mill operation, although some can be modified and applied to certain types of service mill.

MILL MANAGER

Reporting directly to (owner), the mill manager is responsible for the overall, safe, and efficient operation of the mill. Specifically, the duties are:

- To liaise with (owner) on the mill operation on a weekly basis;
- To set standards of performance and targets for the milling operation;
- To delegate authority and responsibility to and to supervise and evaluate performance of the mill staff;
- Directly and in cooperation with other staff to undertake market surveys and development work with the aim of maximizing profits;
- To monitor and verify all incoming and outgoing grain, flour, and other essential inputs and outputs of the mill;
- To monitor and verify all monetary transactions at the mill in accordance with routine acceptable bookkeeping practices;
- To analyze, evaluate, and monitor overall performance of the mill in collaboration with other mill staff;
- To guarantee that stocks of grain, bags, fuel, spare parts, and other essential inputs are maintained at a level that allows for smooth, continuous operation of the mill;
- To monitor and verify any staff claims for expenses, holiday pay, overtime, absenteeism, and so forth;
- To arbitrate any staff problems and difficulties at the mill;
- To prepare a monthly written report on the mill operation including production levels, sales, cost and returns, inventory, and a general narrative description of notable occurrences for submission to (owner); and
- To undertake other duties as are assigned by (owner).

MILL SUPERVISOR

Reporting directly to the mill manager, the mill supervisor is responsible for the day-to-day operation of the equipment at the mill. Specifically, the duties of the mill supervisor are:

- To ensure the continuous operation of the equipment to meet flour quality standards and mill production quotas;

- To supervise the activities of the labourers to ensure continuous and efficient operation of the equipment;
- To liaise regularly with the mill manager on the floor operation of the mill;
- To supervise the cleanup activities of the labourers to ensure that cleanliness of the mill is maintained at all times; specifically, to guarantee that the mill is thoroughly swept at least once a day in addition to other regular sanitation measures;
- To ensure that regular recommended maintenance of engines and equipment is completed;
- To maintain accurate service and maintenance records on the mill equipment in conjunction with the mill mechanic should one be hired;
- To collaborate with the mill manager to arrange for any necessary repairs to the mill equipment;
- In cooperation with other staff and specifically the mill manager to ensure that a minimum of 1 month stock of essential inputs is on hand at all times; and
- To undertake other duties as are assigned by the mill manager.

Note: Depending on the size of the operation, it might be advisable to hire a mill mechanic who would act as an assistant to the mill supervisor. The mechanic would be responsible for regular maintenance and repair of the mill equipment.

COMMERCIAL OFFICER

Reporting directly to the mill manager, the commercial officer is responsible for the maintenance and filing of all record keeping. Specifically, the duties of the commercial officer are:

- To liaise regularly with the mill manager on all production, inventory, and cost and return records;
- To ensure that incoming grains are inspected for moisture, variety, insect infestation, and debris and to reject any that do not adhere to quality standards;
- To ensure that weights of incoming grains and outgoing products adhere to their respective receipts;
- To prepare daily production reports and weekly summaries;
- To prepare weekly and monthly revenue, expenditure, and cost and return reports;
- To maintain a current inventory of grain, flour, and mill inputs;
- To be responsible for all cash transactions at the mill site and to ensure that all sales records are in accordance with approved procedures;
- To undertake market development work with the aim of maximizing profits, as directed by the mill manager; and
- To undertake other duties as are assigned by the mill manager.

Note: Depending on the size of the mill operation, it might be advisable to hire a storekeeper who would act as an assistant to the commercial officer.

LABOURERS

Between four and six unskilled labourers will likely be needed to operate the mill. Their precise duties and responsibilities should be determined under operating conditions. Labourers will be needed to handle grain and to bag and seal the flour.

APPENDIX 6. MILL RECORD SYSTEM

The record system used in the mill should be designed so that it meets the local accounting, production, and maintenance requirements of the mill owners. However, the most important use of the records is to provide management with the tools and information from which to make decisions to improve the efficiency and profitability of the mill.

The system should be as straightforward as possible so that the amount of time needed to complete the forms is minimized, yet, must be sufficiently detailed so that all inputs and all outputs are recorded.

The record-keeping system introduced in this appendix has been used in an adapted form in the continuous-flow mills operating in Nigeria and in Botswana. Under different situations and different operational routines, the system will likely need some modifications. Nevertheless, the approach described below is very important. Similarly, if a service mill is being operated as a combination service/continuous-flow system, then many of the recording forms described below will be needed to register inventory, income, and expenditure.

The entire record system is based on a daily worksheet that is used to prepare weekly summaries, which, are, in turn, used to produce a monthly accounting (and operational) report. The system logically and progressively builds from one form to the next (Append. Fig. 1).

DAILY MILLING WORKSHEET

The record system starts with a daily milling worksheet as the basic building block. The worksheet is completed each day on the mill floor whether the mill is producing flour or not. It is designed to be used as a working record in the mill for basic information that is subsequently recorded on weekly summaries. All daily milling worksheets should be kept on file.

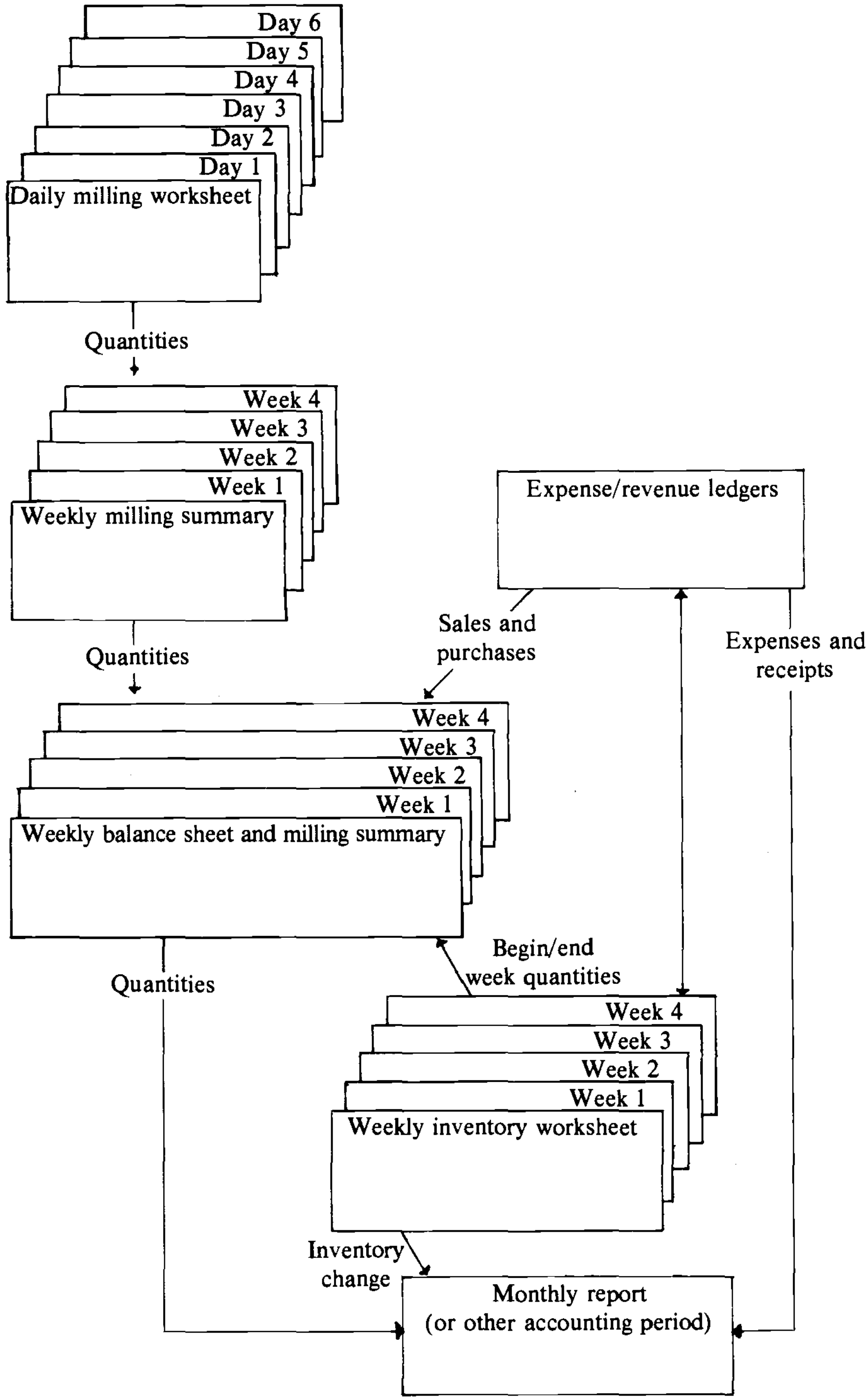
The worksheet can take a number of forms. If it is to record only grain movement, then it should register the amount of grain milled, the amount of bran produced, the amount of flour produced, the quantity of grain lost, or unaccounted for, and the extraction rate. As an alternative, the worksheet can be a record of the disposition of all expendables (fuel, bags, etc.) and a tabulation of labour time for each day that the mill operates. The amount of detail contained in the worksheet will depend both on the analytic needs of the mill manager and on the other records that are used.

It should be stressed that the accuracy of the whole record system depends to a large extent on the accuracy with which the daily milling worksheet is completed. Any errors or discrepancies in converting whole grain into milled products should be reconciled each day. Otherwise, the weekly and monthly reconciliations will become more difficult as daily errors are accumulated.

The following example was designed for use in a mill where only one type of grain is processed each day. If more than one type of cereal is milled in any day, then the form should be adapted to accommodate more than one type, or, alternatively, a new sheet should be used for each grain.

At the end of each day, it is useful to study the worksheet, as it contains two indicators of problem areas:

- Percent loss of, or unaccounted for, grain. Some milling waste is expected because



Append. Fig. 1. Overview of mill recording system.

of dust, stones, scale inaccuracies, weight of packaging materials, and so forth. However, a policy should be set by the management concerning what percentage of unaccountable loss is to be considered acceptable. Only experience can provide a guide, but during the preliminary period of operation, it is suggested that a 3–4% unaccountable loss be considered maximum.

- Extraction rate. The dehuller is capable of operating at an extraction rate of

DAILY MILLING WORKSHEET

Date ______________________

SORGHUM

Whole grain milled ________kg

Bran produced

____

____

__________________ ________kg

Flour produced

2.5 kg × _____ bags = kg

12.5 kg × _____ bags = kg

60.0 kg × _____ bags = kg

Total ________kg

Loss/unaccounted for ________kg

Percent loss/unaccounted for ________

Extraction rate ________%

EXPENDABLES

Fuel

Diesel ________litres

Petrol ________litres

Oil/grease ________(units)

Bags

Used (list sizes) ________

Wasted (list sizes) ________

Other ____

____

____

LABOUR

Name	In	Out	In	Out	Hours

COMMENTS

Signature ______________________

approximately 75% depending on the variety of grain used. After experience has been gained, a policy should be set concerning an acceptable extraction rate. Should the dehuller fail to attain this predetermined extraction rate, some adjustments are likely needed.

As mentioned earlier, a worksheet should be completed for each day. Even if the mill shuts down unexpectedly, the worksheet should be completed with a note indicating why the shutdown was necessary. The daily worksheets are very important not only to maintain inventory control but also to record what has happened in the mill each day.

WEEKLY MILLING SUMMARY

The weekly milling summary simply totals the milling performance for the week. When experience has been gained with the mill, the summary might be eliminated and figures from the daily milling worksheet recorded directly on a slightly revised weekly balance sheet. However, the weekly milling summary is useful particularly during the break-in period because it provides a concise perspective on weekly losses and weekly extraction rates that may help managers to identify problems.

WEEKLY MILLING SUMMARY

For the week of ______________________ to ______________________

Date	Type of grain	Whole grain from storage (kg)	Bran produced (kg)	Flour produced (kg)	Unaccounted for kg	Unaccounted for %	Extraction (%)	Comments

WEEKLY INVENTORY WORKSHEETS

The weekly inventory worksheet is simply a list of the physical quantities of grain, grain products, and supplies that are on hand *at the end* of each work week. The aim is to get as close a measure as possible of the amounts of grain, grain products, and mill supplies on hand so that these quantities can be balanced against the amounts sold, bought, or used during the week.

Values for the inventory only need to be calculated at the end of the week coinciding with the end of the accounting period (say every 4th week). It is often difficult to value inventory properly. The aim should be to use prices that are as close as possible to the market price of the items. A commonly used rule is to value items at their market price, or cost, whichever is the lower. Usually, however, it is more practical to value inputs (expendables) at their cost and milled products at the price for which they are sold.

The easiest procedure to complete the worksheet is simply to walk through the mill in the same direction as the grain flow and record the appropriate physical quantities.

The inventory worksheet is a working document. Consequently, it should be set up to allow sufficient space so that quantities of the same item can be recorded, especially items that are stockpiled in more than one location in the mill.

WEEKLY INVENTORY WORKSHEET

For the week____________________to____________________

Item	Description	Total weight	Value per unit	Total inventory value
Grain				
Sorghum				
Maize				
Other				
TOTAL GRAIN				
Bran				
Sorghum				
Maize				
Other				
TOTAL BRAN				
Flour				
Sorghum				
Maize				
Other				
TOTAL FLOUR				
Supplies/materials				
Poly bags				
Jute sacks				
Diesel				
Petrol				
Oil				
Grease				
Other				
TOTAL SUPPLIES/ MATERIALS				

Signature____________________

WEEKLY BALANCE SHEET AND MILLING SUMMARY

The major weekly summary report is the weekly balance sheet and milling summary. It consists of information collected and recorded on the daily milling summary, the weekly milling summary, the weekly inventory worksheet, and the revenue/expense ledger. The result is a one-page review of the week's technical milling activities.

All the information comes from the other reports and worksheets except for the balance error, which combines actual milling wastes and losses, errors in recording inventory weights and milling weights, and mistakes in accounting for purchases and sales.

The balance error is a useful check for errors, omissions, or actual losses. It is unlikely that every kilogram of grain or flour or every poly bag can be accounted for, but it is possible to establish a maximum balance error allowable before recalculation, weighing, and checking is required. During the break-in period, 3-4% of the total for accountable items might be used as a maximum guide. Nevertheless, the balance error should be as small as possible.

In the same balance sheet, each item row, totals to the left of "Total to account for" should equal the total to the right of "Total to account for."

WEEKLY BALANCE SHEET AND MILLING SUMMARY

For the week ______________________ to ______________________

Item	On hand begin week	Incoming	Produced/ processed/ used	Total to account for	Sales	Used for processing	Balance error	On hand at end of week
	Quantity Units	Quantity Units	Quantity Units	Quantity Units	Quantity Units	Quantity Units	Quantity Units	Quantity Units
Sorghum								
Whole grain								
Dehulled grain	*(from inventory worksheet)*	*(from revenue/ expense ledger)*	*(from weekly milling summary)*	*(sum of first three columns)*	*(from revenue/ expense ledger)*	*(from weekly milling summary)*		*(from inventory worksheet)*
Bran								
Flour								
Maize								
Whole grain								
Dehulled grain								
Bran								
Flour								
Other								
Whole grain								
Dehulled grain								
Bran								
Flour								
Materials/supplies								
Poly bags (list types)								
Jute sacks								
Diesel								
Petrol								
Oil								
Grease								
Other (list)								

Signature ______________________________

REVENUE/EXPENSE LEDGER

The revenue/expense ledger simply organizes the recording of money spent or promised for inputs and money received or promised for outputs. The financial accounting system used in Nigeria and Botswana was not a full double-entry system of debits and credits but proved to be quite adequate. Any number of different ledger systems can be used, and a simple sample of one version is reproduced here.

REVENUE LEDGER

				Value				
Date	Item	Voucher receipt number	Weight/ amount	Cash	Accounts receivable	Sorghum	Maize	Other

MONTHLY COST AND RETURN REPORT

If the accounting period for the mill is every 4 weeks, a final monthly cost and return report is necessary.

EXPENSE LEDGER

				Value					
Date	Item	Purchase order number	Weight/ amount	Cash	Accounts receivable	Milling wages	Fuel	Repairs	Etc.

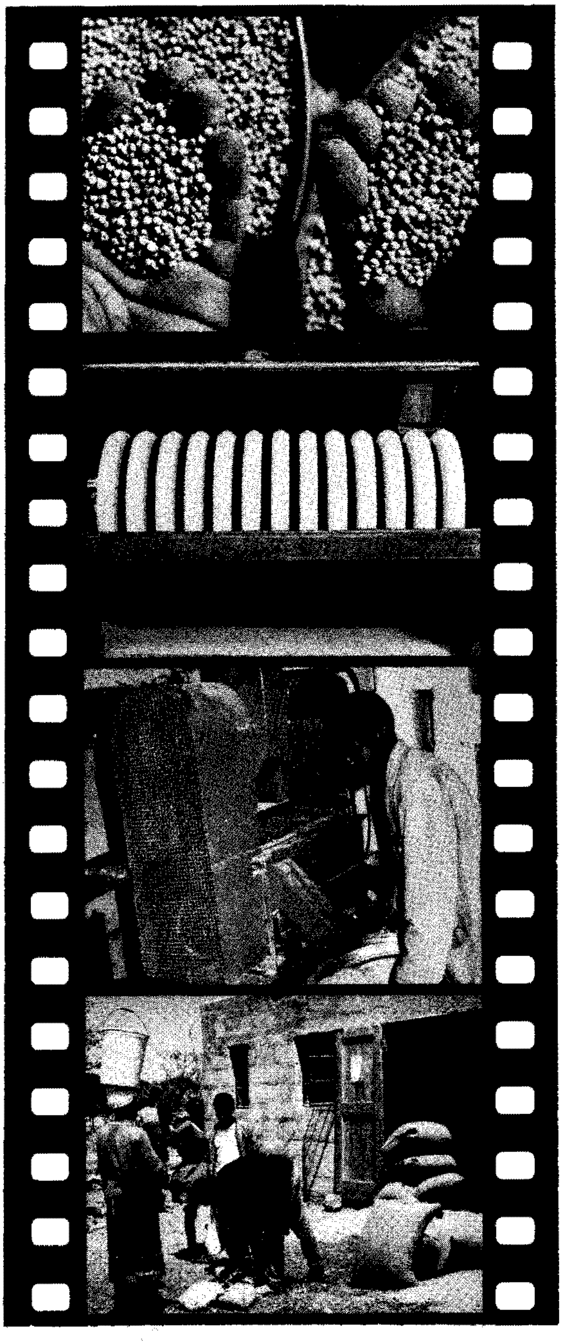
MISCELLANEOUS FORMS

Depending on the accounting system used, various other receipts and cash sales summaries are necessary along with other stock ledgers for spares, tools, and any large depot for grains outside the mill storage. In addition, an equipment and machinery maintenance record should be maintained.

APPENDIX 7. SUMMARY OF ADVANTAGES AND DISADVANTAGES

Criterion	Continuous-flow dry mechanical mill (using PRL/RIIC dehuller)	Service dry mechanical mill (using PRL/RIIC dehuller)	Traditional wet milling (using mortar and pestle)
Mechanical complexity	Most complex but still relatively simple; no high technology	Quite simple	No machinery
Maintenance requirements	Relatively easy to maintain	Quite easy to maintain	Virtually no maintenance
Cost	Highest direct costs but investment is relatively low	Only modest direct cost and investment low	Minimal direct costs but substantial indirect costs such as foregone employment, importing processed flour, displacing farmers, etc.
Dehulling efficiency	Range 75–85%	Range 75–85%	Average 70%
Throughput	Average 4000–5000 kg/d	Variable but capable of a maximum 3000 kg/d running continuously with only one dehuller	With same labour as mill average of 10 kg/d
Nutritional value	Slightly higher protein loss than with traditional methods and modest losses in crude fibre, ash, and fat	Same as continuous-flow mill	Slight losses in protein, ash, crude fibre, and fat
Shelf-life	Relatively long shelf-life; mouldiness and rancidity not a problem	Relatively long shelf-life; mouldiness and rancidity not a problem if the flour is machine dehulled and ground	Very short shelf-life; mouldiness and rancidity a common problem
Consumer acceptance	Acceptable	Acceptable	Acceptable
Sociological implications	Likely to cause some change	Likely to cause little change	Maintains status quo
Employment generation	Likely to stimulate secondary/cottage industry	May stimulate secondary industry	Unlikely to improve employment opportunities
Management	Considerable skills required for successful operation	Few skills required for successful operation	Virtually no managerial skills required
Degree of local support	Some community support essential	Considerable community support essential	No community support needed
Flexibility	Some flexibility	Considerable flexibility	Little flexibility
Effects on self-reliance	May encourage self-reliance	Likely to encourage self-reliance	Completely self-reliant

Technical editing: *Amy Chouinard*



An end to pounding

Filmed and produced by Neill McKee (1980)

This 15-minute educational film tells the story of the PRL/RIIC dehuller and how it may bring a wide range of benefits to both producers and consumers in Botswana. It is available on loan from the International Development Research Centre's Communications Division. A handling fee of $10 (Cdn) is normally required but may be waived in response to requests from libraries, institutions, researchers, and administrators in developing countries.

Send requests to:

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